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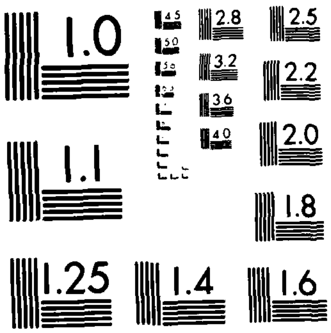

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A MODEL TO INVESTIGATE LOSSES AND EXCHANGE RATIOS IN LARGE-SCALE AIR-TO-AIR ENGAGEMENTS

THESIS

AFIT/GST/OS/83M-1 Roy J. Bogusch
Major USAF

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A computer model, written in FORTRAN 77 and using SLAM structure, was developed to investigate the results of aerial combat between large numbers of modern fighters in a central European scenario. The model is complete and running but only partially verified and is not validated.

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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

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Graduate Strategic and Tactical Sciences

March 1983

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Abstract

There is no available technology for studying the results of tactical air-to-air engagements involving more than 16 aircraft. A computer model based on a central European NATO-Warsaw Pact conventional conflict was built using FORTRAN 77 and the SLAM simulation language. This model allows engagements of 144 aircraft. Blue aircraft operating from CAP patterns defend against Red fighter-bombers escorted by Red fighters. Only two types of aircraft are modeled: the McDonnell-Douglas F-15 and the MIG-23/27. The model is empirically based and simulates the physical movement of the aircraft, radar and visual detection, and employment of radar and heat-seeking air-to-air missiles and aerial cannon.

A MODEL TO INVESTIGATE LOSSES AND EXCHANGE RATIOS IN LARGE-SCALE AIR-TO-AIR ENGAGEMENTS

I. Introduction

In the event of war in Central Europe between the United States (US) and its North Atlantic Treaty Organization (NATO) allies and Russia and the Warsaw Pact (WP), the western powers would be outnumbered in all conventional weapon categories. The Warsaw Pact superiority in aircraft is approximately 3:1 (Ref 4:143). As bad as this number is, it fails to reflect the actual situation if aircraft are apportioned by mission, as called for in operational plans, and then compared. For example, NATO has approximately 100 interceptor/air superiority aircraft in the Central Region. In one possible scenario, these aircraft could face a total of 1000 to 1500 fighter-bombers, escorting air superiority aircraft, and supporting aircraft such as jammers and reconnaissance platforms. This engagement would take place over a period of three to five hours, with the attacking aircraft in one or two waves. This could lead to engagements involving large numbers of aircraft on both sides. Our knowledge of the outcome of such an engagement is at best an educated guess, because no actual engagements of this size involving first-line weapon systems have taken

place nor does adequate technology exist for investigating the outcome by simulation or analytical means. The few instances of employment of modern air-to-air weapons served mainly to confirm the deadlines of current air-to-air missiles (Ref 12:49).

This lack of confidence in our knowledge of the outcome of large engagements has undesirable effects. We depend on the technological superiority of our aircraft and weapons and the skill of our pilots to offset the numerical advantage of the Warsaw Pact. This implies our pilots will have to prevail against odds as steep as 15:1. If we have no clear idea of the outcome of such engagements, we can have little confidence in our force sizing requirements. As matters currently stand, we have no tools available with which to investigate this particular situation. Therefore, the decision was made to attempt a solution to this problem.

Problem Statement

A suitable method for direct investigation of the results of large-scale air-to-air engagements does not exist. Deleterous effects of this deficiency are many, ranging from low confidence in force sizing decisions to lack of suitable input for theater and higher level campaign models. With no suitable investigative tools available, analysts and decision makers are forced to rely on intuition, experience, and extrapolation from small-scale examples.

Research Question

What would be the results of an air-to-air engagement between large numbers of front-line fighters of the Warsaw Pact and NATO in a Central European scenario? Specifically:

1. Are large-scale air-to-air engagements qualitatively different from smaller engagements as shown by the exchange ratios from such engagements?

2. Do the exchange ratios approach those necessary to prevail against the current Warsaw Pact forces?

3. How does the exchange ratio vary as a result of changing the ratio of aircraft involved?

Objectives

The primary objective of this research is to construct a suitable model with which to investigate these questions. Major factors in accomplishing this were decisions about which elements of the air-to-air engagement process to include in the model and at what level of detail. Every effort was made to remove factors not directly influencing the outcome of the engagement. Factors included in the model were modeled as simply as possible and aggregated as much as possible. The desired outcome of this process was a model which preserved the interactions relevant to the outcome of the engagement and which also ran economically

enough on the computer to allow extensive investigation of the research questions.

Scope

This research is aimed solely at the air-to-air engagement portion of a conflict involving first-line Soviet fighter-bombers escorted by first-line Soviet fighters being engaged by first-line US air superiority aircraft. Outside activities which affected the conduct of the engagement were modeled to the extent necessary to capture any influence on the outcome of the engagement. The engagements essentially took place in a vacuum, with the results determined only by the actions of the participants. However, their freedom to maneuver was not restricted in any way other than limitations imposed by physical constraints.

Assumptions and Limitations

Only two types of aircraft are represented in this model. The US/NATO air superiority aircraft ("Blue" fighter) has the characteristics and performance of the F-15. The Russian/Warsaw Pact ("Red" fighter) fighter-bombers and escorting fighters are represented by the MIG-27 and MIG-23, which are essentially the same aircraft in two different configurations, one with air-to-surface weapons and the other with air-to-air missiles. This was deemed appropriate for two reasons. First, these aircraft are the most advanced aircraft on either side in their assigned roles.

Therefore, this provides a worst-case situation for both sides, in that they always do better if confronted with any other aircraft. Secondly, other aircraft which might be included are assigned other missions by their operational plans. This refers specifically to the F-16 which has ground attack as its primary role in this scenario. The decision to include only these aircraft was felt to be necessary to keep the model to a workable size. The number of aircraft of both types was arbitrarily set at 24 Blue and 120 Red. These numbers are sufficient to give the desired engagement sizes and force ratios.

Other limitations include the lack of any provision for Electronic Countermeasures (ECM), communications jamming, or weather effects such as restrictions to visibility. All engagements occur during daylight and in clear weather. Terrain and earth curvature are not modeled. The engagement is three dimensional over a flat surface. Boundaries are not explicitly defined. Action is constrained only by the location of the ground targets, airbases, Combat Air Patrol (CAP) points, aircraft limitations, and the assigned aircraft missions.

Radar search is modeled at an aggregated level. Targets within the limits of an airborne aircraft's radar search pattern are tested against a simple probability of detection function based on range, target size, and radar

type. Visual detection likewise is aggregated and based on range, target size, relative position, and aspect.

Weapon probability of kill is also based on comparison with a random draw. This includes all effects such as reliability of the missile and warhead effects. No partial damage is allowed. The result of weapon employment is either complete survival or kill. This simplifying assumption is based on the fact that no method exists for quantifying degradation of system operation following damage by warheads or bullets. Also, an aircraft damaged by air-to-air missiles or gunfire would in all probability return to base and be lost to the engagement. This is also consistent with the research objective of investigating losses and exchange ratios on an engagement basis. This assumption was used in the AMRAAM QUE and is used in the PACAM model.

Systems reliability is assumed to be 100 percent unless explicitly modeled otherwise. That is, all systems are assumed to operate in their designed manner. Communications are assumed to be 100 percent effective where employed. Resources such as air bases and ground targets are merely reference points and have no bearing on the outcome of the model. Ground defenses are not included in this model.

Structural Model

Action takes place in the three-dimensional volume over a flat surface. There are no explicit limits to this

surface or volume. Position and motion are recorded in terms of a right-hand orthogonal set of axes, oriented so that motion in the "north," "east," and "down" directions is positive. Viewed from above, angular motion in a counter-clockwise direction is positive, as is angular motion toward the "ground" (see Figure 1).

Red aircraft depart their bases on low-level nagi-gation and ground attack missions in groups of 20 to 40 aircraft. These fighter-bombers may be escorted by any number of Red fighters (up to the total number of Red air-craft available). If not detected, they complete a pre-planned route and return to their base. Blue aircraft may be stationed in Combat Air Patrol (CAP) patterns, which are 10 to 12 NM long holding patterns some 20 NM east of the Blue base. The CAP altitude is 20,000 feet and any number of flights may be placed in the CAPs. Blue aircraft may also be launched from their base to any desired point.

In all cases, Blue aircraft maintain radar and visual search, and, if they detect Red aircraft within their areas of responsibility, they attack them using tactics based on the two-aircraft element as the basic fighting unit. Red fighter-bombers generally maintain their forma-tion and course. The exceptions are self-defense in response to an attack on an individual aircraft and missile shots of opportunity which can be taken without breaking formation. These would normally occur when a Blue fighter

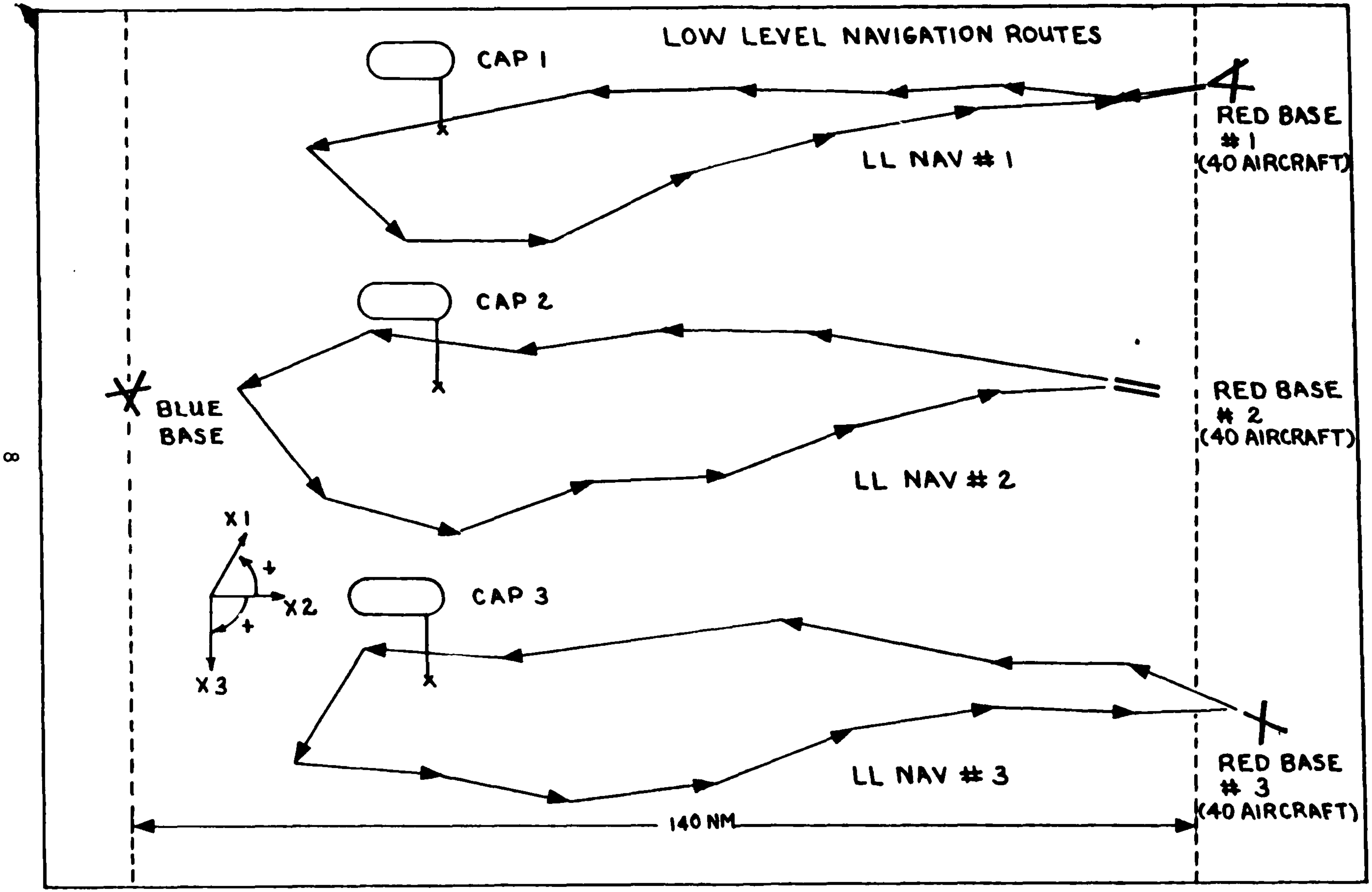

Fig. 1. Air Combat Arena

blundered into a fighter-bomber formation during an attack. Escorting Red fighters rely on four-ship tactics which attempt to bring an opponent under attack from different directions at the same time, enhancing probabilities of an unobserved shot.

For all aircraft, fuel is explicitly modeled and upon reaching predetermined low fuel state ("Bingo"), the aircraft will attempt to disengage and go home. Aircraft can be lost to fuel starvation.

Operating within this framework, Red forces mount offensive missions and Blue forces respond when Red comes within predefined areas of responsibility. Blue aircraft maintain their orbits and if they detect Red aircraft they attack them. If no Red targets appear, the Blue fighters would stay in their assigned area until reaching low fuel state and return home.

Summary

This chapter gave an introduction to the problem and laid out the research to be conducted. The structural model was presented and its operation described. Subsequent chapters will expand the various elements of the problem, the simulation model, and the results of the research.

II. The Model

Problem Structure

The area of the world most likely to produce the type of engagement postulated in the problem statement is the central region of Western Europe, which for US and NATO defense purposes comprises the center third of West Germany. The geopolitical characteristics of that region were used in forming the broad outlines of the structural model. The characteristics of the aircraft used in the model, as mentioned earlier, were based on the F-15 and the MIG-23/27. The performance characteristics of these aircraft and their associated avionics and weapons systems are also incorporated into the model. The tactics used by both sides were designed to take advantage of the strengths of the weapons system and exploit any weaknesses in the opponent. The command and control structure of each side evolved from radically different philosophies, the Soviet/Warsaw Pact system being highly directive in nature and centralized, while the NATO version functions more as an allocation system. All these areas are felt to be of major importance in the model and are discussed more fully in this chapter.

Representative Environment: Western Europe

Western Europe is the only location where the US and Russia directly confront each other with large conventional forces. Both countries have declared that vital national interests are at stake there, so it appears that the greatest change of a large-scale conflict is also there. This is not to disparage the possibility of such a confrontation elsewhere and any conclusions drawn from study of such a scenario should be applicable to other situations where similar forces are engaged. Due to the concentration of forces, however, Western Europe appears to represent a "worst case" scenario and as such was used as the basis for this study.

The Warsaw Pact situation is very simple and quite imposing. Numerous airfields are located in East Germany and Czechoslovakia, the countries facing NATO's Central Region, starting very close to the border and continuing eastward. There are numerous satellite fields, dispersal bases, prepared forward operating locations, and other such sites which give the Warsaw Pact the ability to disperse assets and also move in reinforcements from rear areas, thus bringing their considerable numerical superiority to bear on NATO. These aircraft are supported by one of the most dense radar surveillance nets in existence and controlled by a corresponding communications net. The

overlapping and redundant radar coverage gives the directors of the Warsaw Pact air forces a clear picture of what is happening in the air far across West Germany. This system is the basis for assuming reasonable command and control will be available to the Warsaw Pact air forces, even on attacks deep into NATO territory. For instance, aircraft overhead US bases near the Luxembourg-West German border will be clearly visible on radar if they are above 10,000 feet altitude. This is approximately 100 nautical miles (NM) from the nearest Warsaw Pact radar.

NATO and US forces, on the other hand, are hemmed in by geography. West Germany is only 100 NM wide through much of the Central Region, with many lucrative targets located much closer to the border. This means decreased warning times and time for interception of hostile forces once they enter NATO airspace. To complicate matters further, NATO's tactical radar net is not nearly as extensive as the Warsaw Pact's, which leaves it vulnerable to being destroyed or badly degraded by a few strikes. Therefore, NATO's battle management information and consequent command and control may suffer.

NATO allocates the aircraft under its control to various missions. These missions and allocations are based on an assessment of the shape an attack by Warsaw Pact forces would take. Thus, a total of some 11,000 tactical aircraft available on both sides would not mean an air

battle with this number of aircraft, because the aircraft will be flying different missions. For instance, in NATO, the 75 F-15s at Bitburg Air Base have almost sole responsibility for air superiority in the central region. Other tactical aircraft in the central region are primarily assigned ground attack or interdiction missions in support of ground forces and their contribution to the air superiority effort would be incidental.

On the other side, most NATO plans presuppose a massive Warsaw Pact interdiction effort against selected classes of targets inside West Germany along with sorties flown in support of ground forces. Most estimates call for 1500 to 2500 aircraft to attack in two waves, the first punching corridors in the NATO surface-to-air (SAM) defenses and the second fanning out to attack airfields, munitions storage, command posts, and similar militarily lucrative targets. Thus it can be seen that engagements or series of engagements involving over 1000 tactical aircraft in the space of some two hours might be a very real possibility. Actual engagements would probably be smaller but would still involve over 100 aircraft. This was the actual setting from which the research problem was structured.

Aircraft Performance and Characteristics

Only two types of aircraft, one on the NATO side and one from the Warsaw Pact, are used. The NATO aircraft

considered is the F-15, because it bears the brunt of the defensive air-to-air mission for NATO in the Central Region. The Warsaw Pact aircraft is the MIG-23 Flogger and its ground attack variant the MIG-27. The major difference between the MIG-23 and MIG-27 is the lack of air-to-air radar in the MIG-27, engine inlet geometry which limits the MIG-27 to a lower top speed, and the weapons carried by each aircraft.

Before describing the performance of each aircraft, it is necessary to understand which measures of performance are important in an aerial engagement of this type. Aircraft performance is important, but it cannot be looked at in isolation from such factors as weapon capabilities and command and control structure. The most common criterion is airspeed, and a certain amount of airspeed is desirable. However, results from Southeast Asia and the Middle East suggest that most engagements take place at speeds less than the speed of sound, although aircraft may enter the engagement at higher speeds. Higher airspeeds, particularly above the speed of sound, mean reduced maneuverability, because turn rate and radius are functions of true airspeed and the force supplied by the flight controls. The amount of force available is limited at higher speeds by what the structure of the aircraft can withstand, so the greater the speed, the slower the turn rate and the larger the radius of turn. This maneuverability is important, because to

shoot down another aircraft it is necessary to point your aircraft at him or in his near vicinity, depending on the weapon being employed. This either brings the target aircraft into a missile's field of view or gives the shooter the proper lead angle for a gun shot. As the range between two aircraft decreases, angular rates of motion between them increase for given airspeeds. Thus, the ability to turn the aircraft in effect becomes the ability to employ weapons in a maneuvering environment.

Maneuvering capability in turn is tied to the power available, generally described by thrust-to-weight ratio or pounds of thrust per pound of aircraft weight. When an aircraft turns, it creates additional aerodynamic drag. If it does not have enough power available to compensate for this additional drag, it loses airspeed, which means less maneuvering capability and greater vulnerability to other fighters. This points out another valuable performance characteristic: acceleration, or the ability to gain or lose airspeed quickly. It may be advantageous to run into an engagement at a high speed for surprise and to cut down reaction time for the opponent. Once in the engagement it may be necessary to slow down to make a quick, tight turn to employ weapons. After doing this it is necessary to regain airspeed quickly to have maneuvering potential or separate from the engagement and avoid being a "sitting duck" caught at low airspeed. A high thrust-to-weight ratio

also provides acceleration capability. Modern air superiority fighters generally have thrust-to-weight ratios of .9 to 1.1 or better. For comparison, Korean War jets had thrust-to-weight ratios of 0.5 to 0.6 and Southeast Asia fighters 0.6 to 0.8.

Of course, the maneuverability must be balanced against other requirements. To destroy the opponent he must be found, which for all air superiority fighters means radar. A high-performance search radar normally requires a large antenna. If long range or endurance is required it also means a large fuel load. These two factors drive up aircraft size, size means weight, which requires larger engines to power it, which means more weight and size, etc. A balance must be struck among all these factors based on mission requirements.

With this brief explanation of fighter performance characteristics in mind, let us compare the two aircraft.

The F-15 is a large, single seat, twin-engined air superiority fighter. At combat gross weights its thrust-to-weight ratio varies between 0.9 and 1.1. At best, maneuvering speed of Mach 0.9 it can sustain turns of 13/ second and achieve instantaneous rates in excess of 20/ second. The pulse doppler radar can detect fighter sized targets to 45 NM and is practically unaffected by ground clutter, so that it has the ability to detect targets "looking down" at them. The radar search and track limits

are 60 left and right of and 60 above and below the fuselage center line. It is armed with four semi-active radar guided missiles, four heat-seeking missiles, and a 20 mm cannon, which fires at 100 rounds per second and has nine seconds' ammunition available. It carries enough fuel for approximately 1.0 to 1.5 hours of flight in the scenarios described in this paper, depending on the amount of maneuvering and high power settings required. The pilot is seated well up in a bubble canopy, giving excellent visibility in all quadrants above the wing.

The MIG-23/27 is a medium sized, single seat, single engine fighter with a thrust-to-weight ratio of 0.8 to 1.0. It can sustain 8 to 10/second turn rates and achieve 16/second instantaneously. Its best maneuvering speed is also Mach 0.9. The MIG-23 air-to-air fighter's radar has limits of 45 left and right of and 20 above and below the fuselage center line. The radar has a limited look-down capability at medium and high altitudes. Search range is about 40 NM on fighter sized targets and tracking range is about 25 NM. It is armed with two large air-to-air missiles (APEX) which may have either radar or IR seekers and two to four smaller IR missiles (APHID or ATOLL). A 23 mm cannon with 6 seconds' ammunition is installed. The MIG-27 fighter-bomber has no radar and carries bombs or air-to-surface munitions instead of missiles, although two IR missiles may be carried for self defense. Both aircraft have restricted visibility aft or the cockpit.

The aircraft have an excellent acceleration capability, better than thrust-to-weight figures might indicate, because of their clean aerodynamic design. For those familiar with US aircraft, the MIG-23/27 are similar in performance to the F-14, or one generation behind the F-15.

Weapon Performance and Characteristics

The advent of reliable, capable air-to-air missiles has wrought a revolution in aerial combat. No longer must a pilot close to within hundreds of feet of an adversary and maneuver his aircraft into a small cone behind him to enable him to hold his guns on the opponent long enough to fire sufficient bullets to destroy him. Modern missiles have sufficient maneuverability to deal with most evasive maneuvers. Radar guided missiles can be launched at ranges much greater than 10 NM from the target. These missile capabilities combined with aircraft speeds and long range radar mean the combat arena has expanded enormously.

Such a radical change also implies that it might be necessary to reexamine tactics, performance, and pilot skills to see if current versions are all still applicable. Most radar guided air-to-air missiles in current use are semi-active. This means they have a radar receiver but no transmitter, and pick up radar signals transmitted by the aircraft and reflected from the target. This requires the fighter to lock on to a single target and remain locked on

to it until the missile impacts in order to provide "illumination" for the missile. If the radar lock is lost the missile will go ballistic and not track the target. Radar missiles are relatively slow, and times of flight for launches from the front quarter, such as would be expected at the beginning of an engagement, would be from 20 to 40 seconds. Even though the missile is launched many miles away, the flight time and the requirement for the fighter to maintain radar lock, which means the angular tracking limits of the radar cannot be exceeded, tend to "drag" the fighter to the target. Typically, the fighter is only 2 to 3 NM from the target when the missile impacts, or close enough to be readily seen by any other aircraft in the vicinity.

Radar missiles, then, offer the ability to attack from long range and are unaffected by weather. They are susceptible to countermeasures such as deceptive jamming. A properly-timed maneuver of 5 Gs or more by the target may cause the missile to pass outside the effective warhead radius. These missiles are all aspect, meaning they can be launched from any position relative to the target, but a problem area exists in the beam, or from 70° to 110° off the target's nose. The missile "sees" relative velocity, and in the beam the missile's velocity relative to the target is the same as its velocity relative to the ground. Therefore, if the missile approaches from the beam and

ground returns are present in the missile's field of view, as they would be if the missile were above the target, the missile is likely to transfer lock to the ground and be lost. This does not occur if the missile approaches from below the target or from the nose or tail if above the target. Even with these shortcomings, radar missiles are given a very high PK, or probability of kill. The US expects 0.75, or three out of four, of its radar missiles to do the job (Ref 9). Not as much is known about the Russian APEX missile, but a PK of 0.4 is not unreasonable (Ref 6).

The greatest change in air-to-air missiles has come about in heat-seeking infrared (IR) missiles. These missiles guide on the IR radiation produced by the engines. Until the recent acquisition of the AIM-9L, these missiles were limited in employment to a cone roughly 30° to 45° around a target's tail. The AIM-9L is an all-aspect missile. Its cooled detector is sensitive enough to track the IR emissions from any relative position. This ability, plus improved maneuvering capability, make it an extremely lethal missile (24 hits for 27 launches in the Falkland Islands War) (Ref 5). Russian missiles do not have this capability yet and are still restricted to the stern area for launch.

All IR missiles are "launch and leave" or "fire and forget." The missile is autonomous after launch, tracking and homing on the target at which it was directed. IR missiles are typically shorter range and faster than radar

missiles, with launch ranges being 1 to 3 NM and flight times of 6 to 12 seconds. IR missiles are subject to countermeasures such as flares, but the release of these must be properly timed and the missile's short time of flight does not allow much reaction time. Earlier versions could be defeated by a hard turn as the missile approached intercept, but tests have shown that turns up to 10 G intensity are not enough to move the all-aspect version outside lethal warhead range. For practical purposes the all-aspect IR missile cannot be aerodynamically outmaneuvered by present aircraft once it is launched (Ref 11).

Both the F-15 and MIG-23/27 carry an internally mounted cannon with a high rate of fire. Effective ranges with current sights and flight controls in a maneuvering environment are limited to roughly 2000 feet. A computing gunsight indicates to the pilot where the airplane must be pointed in order for the bullets to strike the target. Once this position is achieved the high rate of fire makes it possible to fire enough rounds in a very short time (1 to 2 seconds) to achieve a reasonable PK. Probabilities of kill are highest in the stern where it is possible to achieve controlled position and stable tracking, and lowest in the front where closing velocities are highest.

Tactics

Tactics are designed to make use of the capabilities of possessed equipment and exploit known weaknesses in an opponent. US tactics assume numerical inferiority, limited to nonexistent command and control and radar assistance, the two-ship element as the basic fighting unit, and allow relative freedom to the flight leader to choose tactics (Ref 1). The Warsaw Pact strives for tactical numerical superiority, employs four aircraft as the basic fighting unit, tries to use set-piece tactics, and relies heavily on radar and radio guidance (Ref 15).

Each US pilot is expected to make full use of his aircraft as a weapon system. There is none of the wingman-leader relationship common in World War II and Korea where the wing man is solely respor ible for protecting the leader. There are simply not enough aircraft not to use each to the fullest. The tactics that evolved envision the element working as a coordinated pair, supporting each other, and doing as much damage as possible while surviving. The pilot expects to detect an opponent at least 30 to 40 NM away, which will allow him to decide the type tactics he wants to employ and execute the initial intercept and attack as he desires. At longer ranges an altitude offset of 5,000 feet to 10,000 feet is taken above or below the target. This helps to prevent or delay acquisition of the fighter by the target aircraft. It is

relatively easy to do because target information such as altitude, airspeed, and heading is displayed on the radar scope. The flight will turn to a course which will reach the targets as quickly as possible and accelerate to an airspeed of Mach 0.9 to 1.2 depending on the leader's preferences and the time available. As the flight closes within tactical missile range the pilots will attempt to launch radar missiles at different aircraft to start the engagement with an advantage. As they close with the target flight, they attempt to visually pick up other aircraft and get off IR missile shots and snap gun shots. Most Russian/Warsaw Pact formations are large and numerous and if a pilot enters a turning engagement with a single aircraft, he allows the other aircraft in the flight the opportunity to maneuver as they please and probably get shots at him. Therefore, tactics emphasize early shots, causing as much disruption as possible, keeping airspeed up, and avoiding getting drawn into the "dogfight" type engagement. Rather, it is desired to go through the formation to a clear area, turn around, and reattack if possible. A rule of thumb says don't turn more than 90° in trying to get a shot at any one target. These tactics exploit the maneuverability of the aircraft and the ability of its avionics to give a fairly clear picture of the situation before entering the engagement.

Russian tactics, on the other hand, integrate ground radar guidance to position the four aircraft of a flight so they can simultaneously launch four radar missiles from the nose and front quarters and then be in position so that if the initial missile attack fails, the fighters will be closing from different parts of the sky and at least one will have an opportunity to launch a missile no matter what way the opponent turns. This would negate an adversary's superior maneuverability. Alternatively, an element might attempt to decoy an intercepting fighter by turning off and "dragging" him in front of a second element, making use of the good speed qualities of the MIG-23. This would be augmented by using ground radar for direction and not turning on the aircraft radar until the last possible moment to avoid warning the intended target (Ref 15).

One step up from basic employment tactics, the defending fighters want to concentrate on fighter-bombers carrying air-to-surface munitions and avoid enemy fighters if possible. The difficulty in this is determining which is which, particularly on radar. Confronted with a large number of radar contacts, most pilots will assume the returns at the lowest altitude are the fighter-bombers and attack them first if possible. However, in a scenario like this one a pilot cannot pass up a group of aircraft without a visual identification, so he must attack the nearest or first group. Defending pilots would continue their attacks

until out of fuel or weapons. The attacking fighter-bombers would attempt to reach their target if at all possible. If directly threatened by an attacking fighter, a fighter-bomber might jettison his ordnance and turn to meet the attack, which would then have accomplished its purpose of disrupting the fighter-bomber's mission. Escorting fighters would attempt to intercept defending fighters and prevent them from attacking the fighter-bombers.

This brief outline describes the actions occurring at the basic level in a large engagement. Larger engagements are generally composed of bigger numbers of aircraft attempting to do the same basic thing and using the information available to them from visual and radar search and radio communications from other flight members and agencies such as ground and airborne radars.

Command, Control, and Communication

The two sides' approaches to command and control reflect very different philosophies. The NATO structure centralizes command but leaves responsibility for execution of directives and plans at the very lowest level. Quite often it is the flight leader who is responsible for selecting tactics and accomplishing the assigned mission within the constraints of other operations and his area of responsibility. The Warsaw Pact, through multiple radar sites

with overlapping coverage, controls execution down to the tactical level (Ref 15).

NATO air defense in the Central Region has a central command center which gets most of its information from a few fixed and several mobile radar units and from the bases where air defense fighters are stationed. The command center functions mainly as an allocation filter, assigning targets to surface-to-air (SAM) sites and airborne fighters. The command center also orders additional fighters launched to replace those returning to base or in response to increased pressure from enemy fighters. Directions are passed from the command center through the radar sites to pilots. The radar controller will give an initial heading for an intercept, but as soon as the pilot has radar or visual contact with the target and can complete the intercept on his own, the controller will stop giving information.

When the pilot reports the intercept complete, the controller will give him a new intercept heading to another target or order a return to CAP or base, depending on the situation. This normally works very well, because the radar in the aircraft is superior to the radar on the ground for intercept, although ground radar has much broader coverage and can form a better overall picture of the situation. It also makes a virtue of necessity because there are fewer controllers than aircraft and one

controller must handle several aircraft. Because there are a limited number of radar sites, pilots must be capable of autonomous operation if the sites are knocked out.

The Warsaw Pact, in contrast, has a multiply redundant radar and radio nét which allows commanders on the ground to direct aerial forces the same way an army commander directs ground troops. Command and control becomes an offensive weapon, shifting forces to concentrate mass or take advantage of weaknesses in the defense. Each fighter unit has its own radar controllers, who in many cases are squadron pilots. They follow the action on radar and direct tactical actions. This direction may be as detailed as when to set switches and launch missiles. This does not imply that the individual Warsaw Pact pilot is incapable of action on his own, just that the system is extremely centralized in all regards.

It should be recognized that these comments apply only at this time. Systems change and evolve. NATO is upgrading its radar sites and communications facilities. Russian cadres are experimenting with "free play" aerial tactics. The effects of this will be seen in the near future.

Conceptual Model

An aerial engagement in the above situation would operate in the following manner. Hostile Red forces,

located some 140 NM from Blue forces, attack in large numbers from several bases and in a variety of formations. The Blue aerial defensive forces attempt to destroy as many Red aircraft as they can after Red aircraft enter their zones of responsibility. They do not have to destroy all the Red aircraft to be successful. In destroying some aircraft they may create enough confusion and panic to cause the rest to abandon their mission and turn back. The "pilots" of the aircraft operate according to their mission and information they receive from the sources normally available to them: radar, visual lookout, and radio communication.

Blue aircraft have only two missions. They are launched from their base to CAP patterns where they wait to detect Red aircraft. Blue aircraft may also be launched from their base directly to areas of increased Red activity. If they detect no targets, they will remain in a CAP or return to base. If they detect targets which meet their commit criteria, they will attack in elements of two aircraft. If they reach low fuel state or deplete their weapons, they attempt to disengage and return to base.

Red aircraft also have two basic missions. The fighter-bombers fly a preprogrammed navigation route at a fixed altitude. If they reach their target they deliver their ordnance and return to base. Fighter-bombers have a limited self-defense capability but would only take shots

at Blue aircraft which fly closely enough in front of them to allow a shot without breaking out of formation. Fighter-bombers may also react defensively, if they detect an attack, by turning hard into it and jettison their ordnance for greater maneuverability. If the aircraft survives the attack, he will return to base.

Red fighters also fly preprogrammed routes while searching for Blue fighters. They may escort fighter-bombers or operate independently. If they detect Blue fighters, they attempt to engage using standard Warsaw Pact tactics. If attacked, they attempt to defend themselves while other members of the flight position for attack. Upon reaching low fuel state or depleting their weapons, they return to base.

The fundamental premise was that the basic elements of the process were not very complicated or even very numerous, as seen above. On the Red side, formations and tactics tend to be rigidly prescribed, so that whatever maneuver is selected will be performed in the same manner and with the same parameters by any flight. There will be a range of success in execution based on time available to execute the maneuver, target reactions, and limits imposed by aircraft performance.

Blue tactics are not prescribed, but through a process of trial and error certain preferred tactics have emerged. These emphasize altitude separation between the

fighters to deny or delay acquisition by the target, altitude separation between the fighters and the targets, and lateral separation between the fighters, all for the same reasons. The fighters attempt to "sort" the target formation on radar to determine target numbers and location, and pick different targets for radar missile launch so as not to shoot at the same target. If range to the target permits, fighters will normally try to offset to a front-quarter position rather than nose-on. This gives a slightly higher PK for missiles and a better opportunity to visually pick up the targets. Pilots hesitate to turn very far to get shots at targets when attacking large formations because of the possibility of flying in front of a hostile aircraft and allowing it a shot. With the short-range capability afforded by all-aspect IR missiles, a pilot can follow an initial radar shot into and through a formation, possibly getting one or two more shots, and separating to a clear area where he can turn around and reattack. Defensive air superiority pilots are primarily interested in attacking fighter-bombers, as their air-to-surface ordnance will do the most damage to resources. It is not possible to identify them on radar, but if a group of targets on the radar scope represent a formation of hostile aircraft, pilots normally assume those at the lowest altitude are fighter-bombers and will attack them initially. Once within visual range, visual discrimination is sometimes possible.

However, pilots are not free to attack fighter-bombers and ignore fighters. Neither can pilots defending an area pass up radar contacts to attack other contacts at lower altitude on the assumption the first contacts were fighters. Thus it can be seen that Blue tactics also boil down to a fairly small selection of maneuvers, with variations in the manner and ranges at which they are executed.

Aircraft performance is modeled at an aggregate level. Aerodynamic response of both aircraft is well enough documented to proceed by calling for a maneuver and getting the resultant turn rate, constrained by aircraft structural limits and airspeed. Airspeed is then adjusted by an appropriate amount. This occurs once a second, so aircraft move in one-second straight paths.

Model Development

The Simulation Language for Alternative Modeling (SLAM) was used in developing the model, but it cannot be called a SLAM model. Only the file structure and time advance features of SLAM were used, with the model features coded in FORTRAN 77. The SLAM language was chosen because the author was familiar with it and using its features avoided having to code the many "housekeeping" details of time advance, file manipulation, and statistical reporting.

The Model

The guiding philosophy in this model was simplicity wherever possible. If it was not relevant and important to the outcome, dispense with it. This was considered necessary to hold coding and running time to an absolute minimum. The engagement arena was modeled as a three-dimensional volume above a flat surface (Figure 1). A "Blue" airbase and three "Red" airbases are located approximately 140 NM apart. The dimensions were oriented so that movements in the "north," "west," and "down" directions were positive. This orientation allows headings to be interpreted in the same manner as in real flight: clockwise when viewed from above is positive and ranges from 0 to 360 degrees. Pitch is negative above the horizontal and positive below it. All dimensions are expressed in feet and all angles in radians. Appendix B explains the mechanization of each of the features of the model.

Aircraft motion proceeds as turn rate in both horizontal and vertical planes, with turn rate a partial function of airspeed and limited by aircraft structural limits. Aircraft velocity is maintained as a unit vector, with the magnitude stored separately. Position and velocity are updated every second. Other information about the aircraft, such as fuel load and fuel flow, weapons load, and current activity is also maintained and stored in aircraft files. (See Appendix A for an explanation of these files.)

Aircraft are assigned certain missions, such as Combat Air Patrol (CAP) or low level navigation and ground attack, through assignment of a mission code which directs them to the appropriate section of the program. This mission code, along with an associated activity code, causes the "aircraft" to perform their "mission" as time is advanced.

Radar detection occurs every five seconds. This time delay attempts to portray the time lag involved in the radar painting the returns on the scope and the pilot interpreting the returns and making a decision about what to do. Further, the pilot does not watch the radar scope continuously but divides his attention between it, visual search, and monitoring aircraft performance. A line of sight is calculated from the fighter to each airborne target. If the target is within the angular limits of the radar, it is put through a range and aspect angle filter and a probability of detection filter. If it passes all these it is considered detected and is stored in a temporary array. After all aircraft have been checked, the closest ten detected targets are stored in a radar file along with the total number of threats.

Visual detection occurs in much the same manner. The target line of sight and elevation angle relative to the fighter's flight path is calculated and the target is placed in one of eight sectors, corresponding roughly to nose, sides, and tail, above or below the wing line, and a

probability of detection assigned based on sector and range. A number is drawn from a uniform (0,1) distribution and compared with the probability of detection. If detected, the target is placed in a temporary array. When finished, the ten closest targets are placed in a visual threat file along with the total number of visual threats. Targets outside 10 NM are ignored in the visual search routine. The routine schedules itself every 3 seconds.

If a target is detected on radar, the fighter will react according to his assigned mission and the range of the target. For example, if the fighter is in a CAP pattern, he will engage a target only when it comes within a certain predefined range. Otherwise it is ignored. When a radar target meets the commit criteria, the fighter's mission code is changed and he begins an intercept. A decision is made whether to attack from above or below the target, if the target's altitude and range allow time to do this. Otherwise an intercept course is computed and the fighter is turned toward it. When the fighter is within tactical missile range, a missile is "launched." The missile is created at the position of the fighter and given an appropriate velocity vector. It is filed in a radar or heat missile file. A heat missile is fired in preference to a radar missile because it doesn't tie the fighter up as long. If a radar missile is launched, the fighter must maintain a radar lockon until the missile arrives at the

target. When missiles are "launched" the operations flag associated with the mission code is changed to reflect this. The missile files are checked and updated on a second-by-second basis. When a missile reaches its point of closest approach to the target,. its probability of kill is determined. For a radar missile, aspect angle and fighter radar lock-on are checked before computing the probability of kill. If successful, the target is removed, its mission code is changed to reflect the method of its destruction, and the time of kill is noted. If the missile does not kill the target, it is removed at the end of its flight time.

Fighters can also make gun attacks on targets. For a gun attack, the fighter must be within gun range (based on target aspect) and must maintain its "nose" on the target for two seconds. If this is done, a probability of kill is calculated.

Aircraft fuel is monitored and if the aircraft fall below a certain state they are routed back to base on a fuel-saving flight profile.

Summary

The empirical basis for the model was presented and operation of the various sections explained. Chapter III will show verification of the operation of these in the model.

III. Verification and Validation

The term verification is used in accordance with Shannon's writings (Ref 16:29-30). This is the process of insuring the model performs as the modeler intended. For this model it was mainly a case of checking the mechanical operation of the various parts, as explained in the following paragraphs. Because of the difficulties encountered in getting the model to work, verification is only partially complete. The verification print statements were left in the model to aid future verification efforts.

Radar Search

An aircraft radar searches a volume of space delimited by its mechanical design and its detection range. For any given radar, the detection range is mainly a function of a the ratio of the strength of the returned signal from the target to the noise or clutter level. The probability of detection of a target can be represented as a distribution based on range (Ref 7:24-32). Because only one type of aircraft was used on each side, only one distribution was needed for each radar because target cross-section remained the same. The probability of detection is based on the radar characteristics of the target and is a function of target range. When the radar detection subroutine

is called, it computes the range and the angular relationship between the velocity vector and the line of sight to each hostile aircraft for each airborne, radar-equipped aircraft. If the line of sight is within the angular limits of the radar, the probability of detection for that range is compared against a uniform (0,1) number drawn from the SLAM uniform number generator. If the probability of detection exceeds the random number, the target is considered detected and filed in a temporary file. The total number of targets detected and the call signs and ranges of the total (up to a maximum of ten) closest detected targets are filed in the aircraft's radar file. The last three lines in Figure 2 are an example of the Radar Threat File for Blue 1. Note that the targets are filed in order of increasing range, with closest target first. The radar search ignores aircraft which are not airborne. An example of the radar operation is shown in Figure 2. Recall that altitudes are negative (X3), angles below the horizon are positive, and angles above the horizon are negative. (A full listing of the radar operating in all its modes is in Appendix B.)

Visual Search

The visual search section operates in the same manner as the radar section. Every five seconds the range and the angular relationship of all airborne aircraft

```
Blue 1,  Mission Code 111,  Speed  610.00 fps,  Time    740.00
Position:  X(1): 10152160.00   X(2): 10149805.00  X(3):  -19732.22
Velocity:  X(1):    -.8631     X(2):     .5044    X(3):    .0268
Red  1  Mission Code 118  Speed  700.00 fps,   Time   740.00
Position:  X(1): 10061952.00   X(2): 10336223.00  X(3):  -1500.00
Velocity:  X(1):    -.3396     X(2)     -.9406    X(3):  .0000
Radar range, Blue 1 to Red  1 is     207897.98 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.49 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   33.88 degrees.
Probability of Radar Detection is  .518. Random number is  .962.
  Red  1 is not detected.
Red  2  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10062428.00   X(2): 10337539.00  X(3):    -1700.00
Velocity:  X(1):    -.3396     X(2):    -.9406    X(3):    .0000
Radar range, Blue 1 to Red  2 is     208856.53 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.41 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    34.15 degrees.
Probability of Radar Detection is .510. Random number is  .231.
  Red  2   is   detected.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10062904.00   X(2): 10338855.00  X(3):   -1900.00
Velocity:  X(1):    -.3396     X(2):    -.9406    X(3):   .0000
Radar range, Blue 1 to Red  3 is    209820.22 feet
Radar detection limits are:
  Elevation:  Upper   -2.00 degrees, Lower   8.00 degrees.
  Target elevation is   3.34 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth   34.43 degrees.
Probability of Radar Detection is  .501. Random number is  .126.
  Red 3 is detected.
Red  4 Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10063380.00   X(2): 10340171.00  X(3):  -2100.00
Velocity:  X(1):    -.3396     X(2):    -.9406    X(3):  .0000
Radar range, Blue 1 to Red  4 is   210788.98 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.26 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   34.70 degrees.
Probability of Radar Detection is  .493. Random number is  .407.
  Red  4   is  detected.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10063856.00   X(2): 10341487.00  X(3):   -2300.00
Velocity:  X(1):    -.3396     X(2):    -.9406    X(3):    .0000
```

Fig. 2. Radar Detection

```
Radar range, Blue 1 to Red  5  is    211762.77 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.18 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    34.97 degrees.
Probability of Radar Detection is  .485. Random number is  .001.
  Red  5   is   detected.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10064332.00   X(2): 10342803.00  X(3):  -2500.00
Velocity:  X(1):    -.3396      X(2):    -.9406     X(3):  .0000
Radar range, Blue 1 to Red  6 is    212741.48 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.11 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    35.23 degrees.
Probability of Radar Detection is  .477. Random number is  .709.
  Red  6 is not detected.
Red  7  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10064808.00   X(2): 10344119.00  X(3):   -2700.00
Velocity:  X(1):    -.3396      X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  7 is    213725.06 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.03 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   35.49 degrees.
Probability of Radar Detection is  .469. Random number is  .013.
  Red  7  is   detected.
Red  8  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10065284.00   X(2): 10345435.00  X(3):   -2900.00
Velocity:  X(1):    -.3396      X(2):    -.9406     X(3):   .0000
Radar range, Blue 1 to Red  8 is      214713.45 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    2.96 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    35.76 degrees.
Probability of Radar Detection is  .461. Random number is  .266.
  Red  8   is   detected.
Red  9  Mission Code 114  Speed  850.00 fps,  Time    740.00
Position:  X(1): 10042000.00   X(2): 10293350.00  X(3):   -11408.03
Velocity:  X(1):    -.1417      X(2):    -.9899     X(3):    .0000
Radar range, Blue 1 to Red  9 is    181134.44 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    1.10 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    22.20 degrees.
Probability of Radar Detection is .741. Randon number is  .148.
  Red  9   is   detected.
```

Fig. 2--Continued

```
Red 10  Mission Code 114  Speed  850.00 fps,  Time    740.00
Position:  X(1): 10042926.00   X(2): 10294530.00  X(3):  -11408.03
Velocity:  X(1):   -.1417      X(2):   -.9899     X(3)     .0000
Radar range, Blue 1 to Red 10 is    181512.22 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    1.09 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    22.66 degrees.
Probability of Radar Detection is  .737. Random number is  .467.
  Red 10   is   detected.
Red 11  Mission Code 114  Speed  850.00 fps,  Time    740.00
Position:  X(1): 10058612.00   X(2): 10302418.00  X(3):   -15309.75
Velocity:  X(1):   -.1903      X(2):   -.9817     X(3):    .0000
Radar range, Blue 1 to Red 11 is     179057.30 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    -.12 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    28.19 degrees.
Probability of Radar Detection is  .758. Random number is  .712.
  Red 11   is   detected.
Red 12  Mission Code 114  Speed  850.00 fps,  Time    740.00
Position:  X(1): 10068238.00   X(2): 10305123.00  X(3):   -15614.13
Velocity:  X(1):    .5163      X(2):   -.8561     X(3):   -.0244
Radar range, Blue 1 to Red 12 is    176588.63 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    -.20 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    31.32 degrees.
Probability of Radar Detection is  .778. Random number is  .687.
  Red 12   is   detected.
Red 41  Mission Code 114  Speed  850.00 fps,  Time    740.00
Position:  X(1): 9923405.00    X(2): 10408900.00  X(3):   -13026.68
Velocity:  X(1):   .1841       X(2):   -.9829     X(3):    .0000
Radar range, Blue 1 to Red 41 is    345693.56 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    -.42 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    18.26 degrees.
Probability of Radar Detection is  .000. Random number is  .284.
  Red 41 is not detected.
Red 42  Mission Code 114  Speed  850.00 fps,  Time    740.00
Position: X(1): 9923903.00     X(2): 10410315.00  X(3):   -13026.68
Velocity:  X(1):   .1841       X(2):   -.9829     X(3):    .0000
Radar range, Blue 1 to Red 42 is     346427.03 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    -.43 degrees.
```

Fig. 2--Continued

Azimuth limits are: +/- 55.00 degrees. Target azimuth 18.47 degrees.
Probability of Radar Detection is .000. Random number is .610.
  Red 42 is not detected.
Red 43 Mission Code 114 Speed 850.00 fps, Time 740.00
Position: X(1): 9922310.00 X(2): 10414745.00 X(3): -19337.86
Velocity: X(1): .1841 X(2): -.9829 X(3): .0000
Radar range, Blue 1 to Red 43 is 350748.31 feet
Radar detection limits are:
  Elevation: Upper -2.00 degrees, Lower 8.00 degrees.
  Target elevation is -1.47 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 18.76 degrees.
Probability of Radar Detection is .000. Random number is .392.
  Red 43 is not detected.
Red 44 Mission Code 114 Speed 850.00 fps, Time 740.00
Position: X(1): 9923019.00 X(2): 10416160.00 X(3): -19337.86
Velocity: X(1): .1843 X(2): -.9829 X(3) .0000
Radar range, Blue 1 to Red 44 is 351355.59 feet
Radar detection limits are:
  Elevation: Upper -2.00 degrees, Lower 8.00 degrees
  Target elevation is -1.47 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 18.99 degrees.
Probability of Radar Detection is .000. Random number is .241.
  Red 44 is not detected.

* Radar Threat File

Nthrt Blue(1) = 10 Time: 740.00 Flag = 1, Msn Code = 111
Threat Call Signs are: 12 11 9 10 2
Threat Ranges are: 176588.63 179057.30 181134.44 181512.22 208856.53

Fig. 2--Continued

relative to each aircraft are computed. If the target is within an arbitrary range of 10 NM for a Blue aircraft or 5 NM for a Red aircraft, a probability of detection is assigned based on the relative position of the target aircraft. These different probabilities of detection are based on the relative frequency with which the sector is searched and the difficulty of seeing an aircraft there. For example, probability of seeing an aircraft behind and below the aircraft is zero. Probabilities and sector boundaries are different for the Red and Blue aircraft because of differences in construction which limit pilot vision in Red aircraft and enhance it in Blue. Cutoff ranges are different because Blue aircraft are almost 50 percent larger in planform than Red. An example of the visual detection process is given in Figure 3.

Intercept

The intercept computation is critical to an aerial engagement. If an aircraft is detected on radar at reasonably long range (20 to 30 NM), the pilot normally will set a source which will reach the target in the shortest possible time, given the initial positions and velocities. Geometrically, it is a triangulation problem, with the requirement being to find the angle between the two aircraft courses which will minimize the time until both aircraft meet. The model accomplishes this by vector methods

```
Blue 1,  Mission Code 120,  Speed  840.00 fps,  Time    890.00
Position:  X(1): 10086981.00   X(2): 10240221.00  X(3):   -1884.40
Velocity:  X(1):    -.7347     X(2):    .4656     X(3):    .4935

Red   3  Mission Code 118  Speed  700.00 fps,  Time    890.00
Position:  X(1): 10087816.00   X(2): 10238329.00  X(3):    -1900.00
Velocity:  X(1):    .2914      X(2):   -.9566     X(3):     .0000
Range, Blue 1 to Red  3 is        2068.12 feet
Visual Detection, Red   3 bears  left of nose 146 degrees.
  He is above the wing line.
Probability of Visual Detection is  .540. Random number is  .449.
  Red   3   is   detected.
Red   4  Mission Code 118  Speed  700.00 fps,  Time    890.00
Position:  X(1): 10087408.00   X(2): 10239669.00  X(3):    -2100.00
Velocity:  X(1):    .2914      X(2):   -.9566     X(3):     .0000
Range, Blue 1 to Red  4 is        730.42 feet
Visual Detection, Red  4 bears  left of nose 160 degrees.
  He is above the wing line.
Probability of Visual Detection is  .780. Random number is  .557.
  Red  4  is   detected.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    890.00
Position:  X(1): 10087000.00   X(2): 10241009.00  X(3):    -2300.00
Velocity:  X(1):    .2914      X(2):   -.9566     X(3):     .0000
Range, Blue 1 to Red  5 is        891.08 feet
Visual Detection, Red  5 bears  left of nose  59 degrees.
  He is below the wing line.
Probability of Visual Detection is  .878. Random number is  .388.
  Red  5   is   detected.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    890.00
Position: X(1): 10086592.00    X(2): 10242349.00  X(3):  -2500.00
Velocity:  X(1):    .2914      X(2)    -.9566     X(3):  .0000
Range, Blue 1 to Red  6 is      2249.15 feet
Visual Detection, Red  6 bears  left of nose  47 degrees.
  He is below the wing line.
Probability of Visual Detection is  .265. Random number is  .043
  Red  6   is   detected.
Red  7  Mission Code 118  Speed  700.00 fps, Time    890.00
Position:  X(1): 10086184.00   X(2): 10243689.00  X(3):  -2700.00
Velocity:  X(1):    .2914      X(2):   -.9566     X(3):  .0000
Range, Blue 1 to Red  7 is       3650.68 feet
Visual Detection, Red  7 bears  left of nose  44 degrees.
  He is below the wing line.
Probability of Visual Detection is  .151. Random number is  .184.
  Red  7 is not detected.
Red  8  Mission Code 118  Speed  700.00 fps, Time    890.00
Position: X(1): 10085776.00    X(2): 10245029.00  X(3):  -2900.00
Velocity:  X(1):   .2914       X(2):   -.9566     X(3)   .0000
```

Fig. 3. Visual Detection

```
Range, Blue 1 to Red  8 is      5059.68 feet
Visual Detection, Red  8 bears  left of nose  43 degrees.
  He is below the wing line.
Probability of Visual Detection is  .105. Random number is  .457.
  Red  8 is not detected.

*  Only the closest visual threat is saved.

Visual Threat:  Blue  1, Call Sign is:  Red 4,  Range is:  730.42 ft.
Blue   1 has tally-ho on Red   4 at Time   891.00
Blue   1 reacting visually to  Red  4,  Time    891.00
Blue  1, gun kill on Red   4, Time:    892.00
```

Fig. 3--Continued

as described in Chapter II. Figure 4 shows the positions and angular relation once the intercept has stabilized, and the computed intercept point and time. The fighter's velocity vector does not precisely match the intercept vector (Int vec) because the fighter is maintaining his altitude until within 8 NM of the target. A complete sequence of intercept readouts from initial contact to missile launch is in Appendix B.

```
Target Red  1, altitude  1500.00 ft.  Attack will be from above.
     Attack altitude    9500.00 ft.
Blue 1 intercepting Red  1, Range  21.08 NM, Time    803.00
Missile Employment Ranges are:
  Radar Missiles:  Max Range:  46592.45 ft, Min Range:  12883.56
  Heat Missiles:   Max Range:  20450.34 ft Min Range:   5129.40
Intercept Calculations: Ftr Blue 1, Tgt Red 1, Intcpt in  84.12 seconds
Ftr Speed  840.00 fps, Tgt Speed  700.00 fps.
Ftr pos:   X(1): 10133970.00   X(2): 10185384.00  X(3):   -9653.52
    Vel:   X(1):      -.6573   X(2):       .7537  X(3):    .0000
Tgt pos:   X(1): 10070680.00   X(2): 10294609.00  X(3)    -1500.00
    Vel:   X(1):       .2914   X(2):      -.9566  X(3):    .0000
Ftr LOS:   X(1):      -.5003   X(2):       .8634  X(3):    .0645
Int vec:   X(1):      -6529    X(2):       .7486  X(3):    .1154
```

Fig. 4. Intercept

Visual Engagement

Normally, targets are first detected on radar and the initial maneuvers are intercepts. After the aircraft have closed to visual range, it is quite common to see the aircraft which is the target of the intercept and possibly others in the vicinity. In attacking a formation, pilots would like to be able to launch a radar missile from beyond visual range and follow it in, possibly getting more shots

as other aircraft in the formation are visually acquired. It is considered an advantage to get the first kill in an engagement, as this cuts down the odds and demoralizes the opponents. In this model pilots look for aircraft which might be targets and react to aircraft which are attacking them. (An attacking aircraft is defined as one which is within 3 NM and has its nose pointed at the aircraft.) If an aircraft has a radar missile in flight it will ignore visual sightings unless an aircraft is attacking it, in which case it will react to defend itself. The gun and the IR missile are the primary weapons in the visual engagements.

Weapons Employment

The capability of various aircraft/weapon combinations are well documented, although with less certainty for Red aircraft. Where doubt existed, Red was assumed to have the capabilities of a US F-4 Phantom so far as missiles and radar performance are concerned. When the arbitrarily defined tactical ranges of the missiles were met, the missiles were launched. These ranges are based on the relation of the launching aircraft to the target, being greater from in front and diminishing toward the stern. The missiles are flown out to the target, using an average constant velocity, which is not an unrealistic assumption over the ranges involved. Once the missile reaches the target, a probability of kill is determined by comparing a random

number of an arbitrary probability of kill (Pk). For radar missiles this Pk is based on aspect, being lower in the beam (side) areas than in the stern or nose quadrants. Red missiles also have a lower Pk based on technological factors. Blue IR missiles have a constant Pk from all aspects. An example of a Blue IR missile shot is seen in Figure 5. (The same section of the program handles Red IR missile shot also.) Red IR missiles are effective only in the stern area, and outside this the Pk is zero. The probabilities assigned to the missiles are designed to take into account all the miscellaneous items such as reliability, guidance, and warhead lethality. Gun shots are given a fairly low Pk befitting their probable manner of use in this scenario. In multi-aircraft engagements such as this it is generally considered too dangerous to take the time to maneuver to gain a position which would afford a good gun shot, so gun shots are shots of opportunity, taken in haste and without time to refine the parameters. In the model, a successful gun shot requires two seconds of cannon fire, from within a 2500 foot range with the nose on the target aircraft. If this is achieved the gun shot is considered successful.

Low Level Navigation

The Red fighter bombers fly a predetermined low level route at an altitude of 1500 feet and an airspeed of 420 knots (700 fps). At each of the waypoints on the route

```
Heat missile section, Target is Red 1 Speed 2000.00 fps, Time 843.00
Missile position: X(1): 10108014.00  X(2): 10228023.00  X(3): -10838.97
        Velocity: X(1):   -.8796     X(2):     .4712    X(3):    -.0660
Target position:  X(1): 10102130.00  X(2): 10229725.00  X(3): -11241.34
        Velocity: X(1):   -.4062     X(2):    -.9138    X(3):     .0000
Previous range:  8066.95, Current Range:  6138.42,  Delta:  1928.5


Heat missile section, Target is Red 1 Speed 2000.00 fps, Time 847.00
Missile position: X(1): 10100553.00  X(2): 10226463.00  X(3): -11249.13
        Velocity: X(1):   -.9589     X(2):    -.2792    X(3):    -.0506
Target position:  X(1): 10100750.00  X(2): 10226617.00  X(3): -11241.34
        Velocity: X(1):   -.4062     X(2):    -.9138    X(3):     .0000
Previous range:  1076.38,  Current Range:   250.17,  Delta:   826.2


Heat missile section, Target is Red 1 Speed 2000.00 fps, Time 848.00
Missile position: X(1): 10100091.00  X(2): 10224517.00  X(3): -11224.80
        Velocity: X(1):   -.7870     X(2):    -.6161    X(3):    -.0311
Target position:  X(1): 10100405.00  X(2): 10225840.00  X(3): -11241.34
        Velocity: X(1):   -.4062     X(2):    -.9138    X(3):     .0000
Previous range:   250.17,  Current Range:  1359.85*  Delta:   -1109.7
```

* A negative "Delta" indicates the missile has passed the target, and a determination of missile success is made.

```
Missile passed target, kill determination:
                    Pk =  .7500, Random Number =  .7442, Target is dead.
Red 1 shot down by heatseeker, Time:              848.00
```

Fig. 5. IR Missile Flyout

the aircraft turn when within 3,000 feet of the point. The last point is the base and the aircraft lands. This sequence is shown in Figure 6.

CAP Patterns

Blue aircraft are initially in CAP patterns which are racetrack shaped, 12 NM long, and flown at 20,000 feet altitude. Blue aircraft remain there until they detect hostile aircraft, are attacked, or reach a low fuel state and go home. Figures 7a to 7d are printouts of Blue aircraft in a CAP pattern. These patterns are normally specified in terms of a geographic point, an inbound heading to that point, and a pattern length. It can be seen in the figure that the aircraft conform to the pattern parameters.

Validation

Validation of a model which represents a process or situation such as this presents inherent problems. The most obvious one is that there are no actual results with which to compare the model results. Indeed, the purpose of building the model was to obtain these results. Therefore, it was necessary to proceed by indirect means. In a case such as this where actual results are not available, face validity becomes very important. The author attempted to build into the model the essential elements of a large aerial engagement, based on 12 years' experience in tactical fighters and numerous suggestions from other

```
Red   1 departed Base  1 on Route  1  Time:      12.00
Waypoint  1,  Route #  1,  Red    1,  Time:     611.00
Range to Waypoint  1    2597.93 ft.
Ftr pos:   X(1): 10090100.00  X(2): 10422596.00  X(3):    -1500.00
Waypt Pos: X(1): 10090000.00  X(2): 10420000.00  X(3):         .00

Waypoint  2,  Route #  1,  Red    1,  Time:     747.00
Range to Waypoint  2    2330.86 ft.
Ftr pos:   X(1): 10060586.00  X(2): 10332256.00  X(3):    -1500.00
Waypt Pos: X(1): 10060000.00  X(2): 10330000.00  X(3):         .00

Waypoint  3,  Route #  1,  Red    1,  Time:    1031.00
Range to Waypoint  3    2702.71 ft.
Ftr pos:   X(1): 10119052.00  X(2): 10142531.00  X(3):    -1500.00
Waypt Pos: X(1): 10120000.00  X(2): 10140000.00  X(3):         .00

Waypoint 4,  Route #  1,  Red    1,  Time:    1261.00
Range to Waypoint  4    2888.15 ft.
Ftr pos:   X(1): 9978559.00   X(2): 10073339.00  X(3):    -1500.00
Waypt Pos: X(1): 9976000.00   X(2): 10072000.00  X(3):         .00

Waypoint 5,  Route #  1,  Red    1,  Time:    1514.00
Range to Waypoint  5    2637.14 ft.
Ftr pos:   X(1):  9999644.00  X(2): 10237387.00  X(3):    -1500.00
Waypt Pos: X(1): 10000000.00  X(2): 10240000.00  X(3):         .00

Waypoint  6,  Route #  1,  Red    1,  Time:    1769.00
Range to Waypoint  6    2523.87 ft.
Ftr pos:   X(1): 10059082.00  X(2): 10405649.00  X(3):    -1500.00
Waypt Pos: X(1): 10060000.00  X(2): 10408000.00  X(3):         .00

Waypoint  7,  Route #  1,  Red    1,  Time:    2392.00
Range to Waypoint  7    2649.24 ft.
Ftr pos:   X(1): 10119869.00  X(2): 10837354.00  X(3):    -1500.00
Waypt Pos: X(1): 10120000.00  X(2): 10840000.00  X(3):         .00

Red    1 landed at Time:    2392.00
```

Fig. 6. Low Level Navigation

```
CAP 1 range is   1.4 NM
CAP 1 location is  X(1): 10154269.00  X(2): 10183851.00  X(3): -20000.00
Blue  1 headed outbound in CAP 1, Theta =     .0461, Time:    523.00

Blue 1, CAP # 1, Speed  585.00, Time    523.00
Position:  X(1): 10162814.00  X(2): 10183835.00  X(3):   -19987.00
Velocity:  X(1):    .1326      X(2): -.9912       X(3)       .0000
Blue 2, CAP # 1, Speed  585.00, Time    523.00
Position:  X(1): 10164714.00  X(2): 10185639.00  X(3):   -19987.00
Velocity:  X(1):    .1326      X(2): -.9912       X(3):      .0000
```

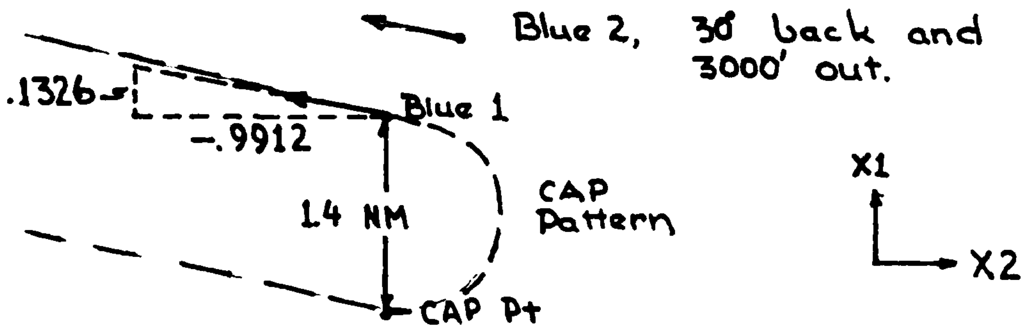

Fig. 7a. CAP Pattern

```
CAP 1 range is   12.1 NM
CAP 1 location is X(1): 10154269.00  X(2): 10183851.00  X(3): -20000.00
Blue  1 turning inbound  in CAP 1, Time:     644.00

Blue 1, CAP # 1, Speed  585.00, Time    644.00
Position:  X(1): 10172252.00  X(2): 10113655.00  X(3):   -19987.00
Velocity:  X(1):    .1326      X(2):  -.9912      X(3):      .0000
Blue 2, CAP  #1, Speed  585.00, Time    644.00
Position:  X(1): 10174152.00  X(2): 10115459.00  X(3):   -19987.00
Velocity:  X(1):    .1326      X(2):  -.9912      X(3):      .0000
```

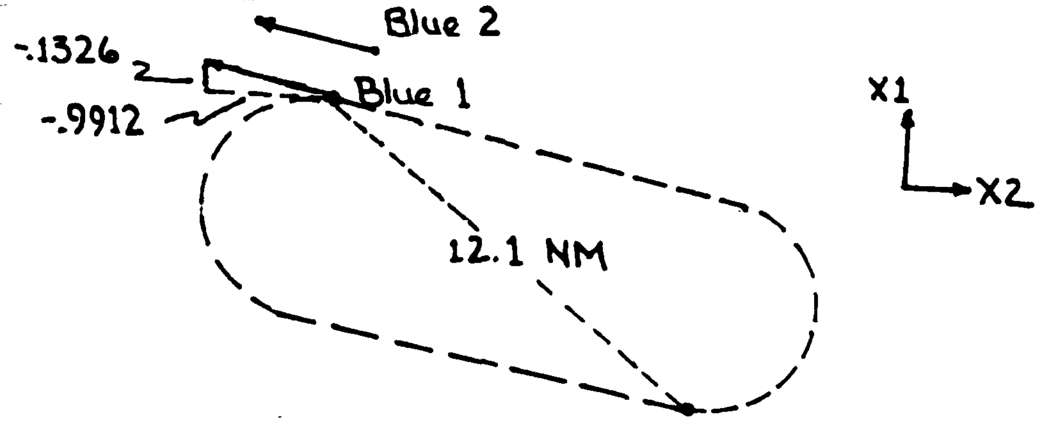

Fig. 7b. CAP Pattern

CAP 1 range is 12.1 NM
CAP 1 location is X(1): 10154269.00 X(2): 10183851.00 X(3): -20000.00
Blue 1 headed inbound to CAP, Time: 667.00

Blue 1, CAP # 1, Speed 585.00, Time 667.00
Position: X(1): 10163861.00 X(2): 10111955.00 X(3): -20000.04
Velocity: X(1): -.2630 X(2): .9648 X(3): -.0002
Blue 2, CAP # 1, Speed 585.00, Time 667.00
Position: X(1): 10161961.00 X(2): 10110152.00 X(3): -20000.04
Velocity: X(1): -.1322 X(2): .9912 X(3): .0000

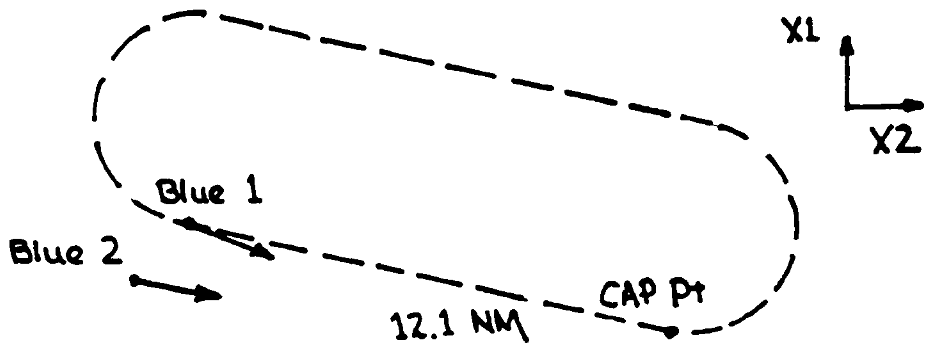

Fig. 7c. CAP Pattern

CAP 1 range is .5 NM
CAP 1 location is X(1): 10154269.00 X(2): 10183851.00 X(3): -20000.00
Blue 1 turning outbound in CAP 1, Time 786.00

Blue 1, CAP # 1, Speed 585.00, Time 786.00
Position: X(1): 10154698.00 X(2): 10180975.00 X(3): -20000.04
Velocity: X(1): -.1322 X(2): .9912 X(3): .0000
Blue 2, CAP # 1, Speed 585.00, Time 786.00
Position: X(1): 10152798.00 X(2): 10179172.00 X(3): -20000.04
Velocity: X(1): -.1322 X(2): .9912 X(3): .0000

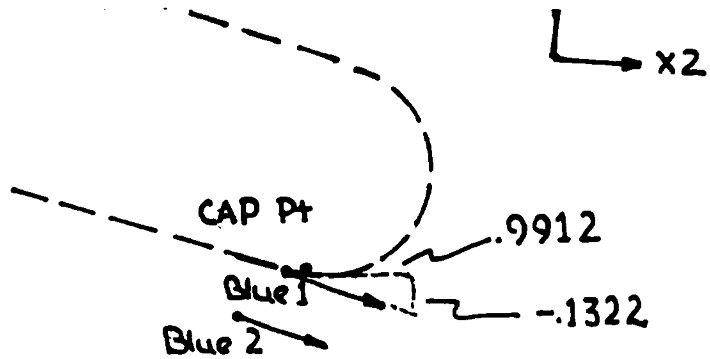

Fig. 7d. CAP Pattern

experienced tactical pilots. Turing tests, where the simulation results are shown to persons knowledgeable about the process and they are asked whether or not they are reasonable, are probably the best available tool in this situation. However, there was insufficient time to conduct these tests after the model was constructed. The AIMVAL-ACEVAL trials quoted by Hodnett and Musson (Ref 7:75-76) were judged not useful for validation of this model. These trials were limited to a maximum of four aircraft on each side, with the majority of the trials being 2 Blue fighters against four Red. Also, the Red aircraft were equipped with advanced IR missiles, which they do not have in this model or in actuality. Therefore, it was felt the results of the AIMVAL-ACEVAL trials and this simulation should not be compared. One set of test results is available which is applicable in some degree. The Air Force Test and Evaluation Center (AFTEC) conducted an Operational Utility Evaluation of the Advanced Medium Range Air-to-Air Missile (AM-RAAM) using the McDonnell-Douglas simulator facility in St. Louis, Missouri. The evaluation compared the use of the AIM-7F missile, which is used in this model, with AM-RAAM under like scenarios. Full data is available on all phases of the evaluation. The simulation used man-in-the-loop throughout. The only drawback is that the computer limited the simulation to a maximum of 12 aircraft: four Blue, four Red fighters, and four Red fighter-bombers which flew "canned"

routes. Data from the applicable segments are used to provide a baseline with which to compare results of this model because they are the only data available. Readers with proper clearances are referred to Reference 7. The problems encountered with getting the model to work properly prevented any attempt at validation of output from the model. The approach employed in building the model was discussed with experienced tactical fighter pilots and there was general agreement that it appeared intuitively appealing. However, with no output, further checks could not be run.

IV. Conclusions and Recommendations

Data is collected on the variables shown in Figure 8. As each of the events occurs, a SLAM global variable is incremented. At the end of the simulation Subroutine OTPUT is called and writes these variables to a file for future analysis by any of the available statistical packages such as Statistical Package for the Social Sciences (SPSS) or BMPD. If desired, a trace may be obtained of any of the several elements of the model, including weapons employment events, position and velocity coordinates, and radar file printouts. This is done by setting the start and stop times for the desired trace in Subroutine INTLC. These set logical switches which operate "write" statements at the desired times.

XX(1):	BLUE Aircraft	XX(8):	BLUE IR kills
XX(2):	RED Aircraft	XX(9):	BLUE Gun shots
XX(3):	BLUE Losses	XX(10):	BLUE Gun kills
XX(4):	RED Losses	XX(11):	RED Radar missiles
XX(5):	BLUE Radar missiles	XX(12):	RED Radar kills
XX(6):	BLUE Radar kills	XX(13):	RED IR missiles
XX(7):	BLUE IR missiles	XX(14):	RED IR kills

Fig. 8. Model Variables

Unfortunately, it required so much time to get the model running properly there was no opportunity to collect and analyze data. A sample of the weapons employment trace

is shown in Figure 4. The data graphics capability of SLAM can also be used to get graphs of the values of any of the variables over time.

The experimental design envisioned a series of 5 runs of each combination of 4 and 8 Blue aircraft, 16 Red fighter-bombers, and 8, 16, 24, and 32 Red fighters. Analysis would be done on the effect of the beginning ratios of aircraft engaged to the losses on each side and the exchange ratio, or number of Blue losses to the number of Red losses.

Conclusions and Recommendations

Although there was no opportunity to experiment with the model, several conclusions can be drawn from the process of building it.

The VAX 11/780 computer with the UNIX operating system is an excellent tool for building programs of this nature. It allows easy manipulation of files and code and turnaround is very quick on simulation runs. A subset with four Blue fighters and eight Red fighter-bombers went through a series of five complete runs in 6.5 minutes. With response times as short as this, it is possible to make changes and see the results quickly.

The UNIX FORTRAN 77 compiler was a source of some frustration. It did not catch minor errors in format statements and these would subsequently cause the program

to bomb. Also, if format statements ran over 3 lines in length, the loader had trouble assembling them and would quit with "Termination Code XXX" message that offered no help.

There are several options available with the compiler. One of the most useful was "-C" which checked array subscripts to catch errors caused by exceeding array boundaries. However, this option would not work if any program unit exceeded approximately 700 lines. It would give compiler and assembler errors with no indication of what the problem was. It is also very slow, taking 5.0 to 7.5 minutes to compile the program for the model. Compiling without the "-C" option took only one-third the time. Also, the model ran much more slowly when it was compiled with the "-C" option. The best course seemed to be compiling with the "-C" option while debugging the program and not using it after all the bugs were out. The compiler's diagnostics were quite often cryptic and there was no available documentation to help decipher them (e.g., "Branch too far" and "Segmentation Fault"). Because the VAX computer and the UNIX operating system were both new to the School of Engineering, there were no experienced persons to which to go for advice, and this undoubtedly increased the length of time required to get the program running.

Another problem encountered was refusal of the program to bomb when it encountered a previously undefined

variable during execution. Undefined variables were set to zero and the program would continue running (incorrectly, of course).

The model appears to be running with no further coding or logic errors. Several sections were shown to be running correctly in the verification section. However, the model is in no sense completely verified. The aircraft "flew" in the desired manner and turn performance was consistent with the real world in terms of turn rate and radius. Weapons employment took place at the desired ranges and missile flyout times were reasonable. Radar and visual detection functioned correctly.

Recommendations

The model appears to be a useful, fast-running tool for investigating large air-to-air engagements. The next step would be inclusion of further print statements to complete verification under a variety of scenarios and numbers of aircraft. Once the user was satisfied with the operation of the model, sensitivity analysis should be run on all phases of its operation to see if there are any cases which might bias results. For instance, the results appeared to be sensitive to the scheduling of Red aircraft. If the Red aircraft did not arrive close together, they were destroyed piecemeal. This might leave the false impression that the Blue aircraft were very capable in multi-threat environment.

The experiment which was planned to run with this model involved a series of five runs each with all combinations of 2 and 4 Blue aircraft, 8 Red fighter-bombers, and 8, 16, 24, and 32 Red escort fighters. The objective was to see if the loss rates differed significantly from the low to high ratios of forces engaged, and whether there was a significant difference between the outcomes of the engagements with 2 and 4 Blue fighters.

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Appendix A

SLAM Implementation of the Model

This model is implemented in SLAM and FORTRAN on the VAX 11/780 computer. Ten user files and a maximum of ten attributes are used. NSET/QSET is dimensioned to 15,000 and actual use of the array is just under 9,000 words, leaving some 5,000 + words for recording of plot variables if desired. The model is combined continuous-discrete. No difference or differential equations are used. The continuous feature is used to accomplish periodic updates of aircraft and missile positions. There is no network and the SLAM input file is only five lines. (Fig III-1)

```
GEN,BOGUSCH,THESIS ,3/9/83,1;
INIT,0,2000;
LIMITS,10,10,600;
CONTINUOUS,0,2,.1,1.0;
TIMST,XX(1),BLUE AC;
TIMST,XX(2),RED AC;
TIMST,XX(3),BLUE LOSSES;
TIMST,XX(4),RED LOSSES;
FIN;
```

Example of SLAM Statement File

The files are arranged and used as follows:

File 1, Aircraft Flight Information

Attribute #	Use
1	X1 position (feet, north-south)
2	X2 position (feet, east-west)
3	X3 position (feet, altitude)
* 4	X1 velocity component
* 5	X2 velocity component
* 6	X3 velocity component
7	Airspeed (magnitude, feet/sec)
8	Fuel flow
9	Desired airspeed
10	Desired altitude

* Velocity components are normalized so velocity vector is a unit vector.

File 2, Aircraft Operational Information

Attribute #	Use
1	Wingman call sign
2	Fuel (pounds)
3	Radar missile (4)
4	Heat missiles (4)
5	Seconds of cannon fire (9)
6	Flight size and position within flight
7	Radar and visual detection flag
8	Blue - unused
** 9	Mission status flag
* 10	Mission code

*Current mission codes are:

< 110	Not available for flight
110	Available for mission assignment
111-113	Blue aircraft assigned to CAP 1,2,3
118	Red aircraft on low level navigation and ground attack
119	Bingo aircraft returning to base
120	Bingo aircraft engaging radar contact
121	Blue aircraft engaging visual contact

** The status flag indicates what phase of the mission the aircraft is in, such as turning inbound or outbound in the CAP pattern for Mission Codes 111, 112, and 113.

File 3, Blue Radar Missile File

Attribute #	Use
1	X1 position
2	X2 position
3	X3 position
4	X1 velocity component
5	X2 velocity component
6	X3 velocity component
7	Airspeed (magnitude in feet/sec)
8	Remaining flight time
9	Target call sign
10	Previous range to target

Each Blue aircraft has one entry in the Blue missile file. These are initialized to zero. If a Blue aircraft launches a radar missile, the information is loaded into the aircraft's slot in the missile file. Because an aircraft can guide a radar missile at only one target at a time, this suffices. Any missiles in the missile file are updated until they reach point of closest approach to the target or flight time goes to zero, and they are removed by zeroing the entries.

File 4, Blue Heat Missile File

The attributes have the same information as in File 3. There is no need to identify a heat missile with its launching aircraft as the missile is autonomous after launch. Therefore there is no

set number of entries in the heat missile file. As heat missiles are launched, they are placed into the file. As they reach their targets or run out of flight time, they are removed from the file. Any missile present are updated periodically by Subroutine STATE.

File 5, Combat Air Patrol (CAP) Information

Attribute #	Use
1	X1 coordinate of CAP point
2	X2 coordinate of CAP point
3	Lowest Unassigned Altitude (min 20,000')
4	Cosine of Outbound Heading
5	Sine of Outbound Heading
6-8	Unused
9	Number of assigned flight
10	Number of flights in CAP

There are currently three CAPs defined.

File 6, Red Flight Information

This file is analogous to File 1, and holds the flight information for Red aircraft.

File 7, Red Operational Information

This file has the same information as File 2, except for

Attribute 8 and 9 when the mission code is 118 (Low Level Navia-tion).

Mission Code 118

8: Route Number
9: Way Point Number

File 8, Red Radar Missiles

File 9, Red Heat Missiles

These files are exactly like Files 3 and 4 and hold missile information for Red missile launches.

File 10, Low Level Route Waypoints

Attribute #	Use
1	X1 coordinate of waypoint, Route #1
2	X2 coordinate of waypoint, Route #1
3	X1 " " , Route #2
4	X2 " " , Route #2
5	X1 " " , Route #3
6	X2 " " , Route #3
7	X1 " " , Route #4
8	X2 " " , Route #4
9	X1 " " , Route #5
10	X2 " " , Route #5

Entry 1 holds the first waypoint for Route 1-5. Entry 2 holds the second waypoint, and so on. The last entry for a route

is the base coordinates. The entry following the base coordinates is 999, which "lands" the aircraft when it reaches base.

These files are used mainly as information storage. With the exception of the heat missile files, entities are never filed or removed. Values of the attributes are changed by direct access, which in SLAM works as follows:

Files in SLAM are merely reserved locations in the QSET/NSET array. Each entry in a file requires four words plus the number of attributes declared in the LIMITS statement (Fig III-1), in this case, 10 words. Therefore, each entry requires 14 storage locations in the file. The extra four locations hold linking information to tie the entry to the preceding and succeeding entries. SLAM stores entries in logical rather than physical sequence, so this linking information is necessary. SLAM maintains the address of the first entry in the file, and from this the location of any subsequent entry may be determined. The SLAM function for determining the address of the entry with rank NRANK in file NFILE is

LOCAT(NRANK, NFILE)

Thus, NTRY = LOCAT(5 , 1) returns the address of the first word of entry number 5 in file 1. Attributes of an entry may be accessed by QSET(NTRY + <Attribute Number>). Thus after using the LOCAT function above, the location QSET(NTRY + 7) holds the airspeed of aircraft Blue 5. Other functions which return

addresses of the first and last entries respectively in file NFILE. To step forward or backward through a file, the functions NSUCR(NTRY) and NPRED(NTRY) return addresses of the succeeding and preceeding entries to NTRY. In all cases, if there is no entry, an address of zero is returned.

The only caveat in using direct access of attributes is that an attribute used for ranking entries in the file should not be changed in this manner. The default ranking mechanism of FIFO (First In, First Out) is used in all cases, so this is not a problem. Having determined the organization of the files let us examine the operation of the SLAM program.

In the combined continuous-discrete mode of operation, SLAM advances simulated time based on two criteria: next event time, and step time. In the discrete mode, events are scheduled to occur at some future time by being placed on the next event calendar (NCLNR) in order of event time, lowest value first. The simulation proceeds by advancing time (TNOW) to the event time of the next event on the calendar, executing that event, then advancing to the next event time, and so on, thus advancing from event to event. In the continuous mode, time is advanced by a fixed increment, specified in the CONTINUOUS statement (Fig. III-1). On-going continuous processes are updated and any state variables are checked for the occurance of a state event, which is just the passing of a specified level by a state variable. If a state event has occurred, the step size is reduced (down to an

arbitrary size) and values recomputed, to locate the occurance of the state event as precisely as possible. SLAM updates state variables by calling Subroutine STATE at each step time (DTNOW). STATE normally contains the equations defining the state variables. In this model there are presently no defined state variables, and the continuous time advance mechanism is used to update the position and velocity vectors of aircraft and missiles every second.

Discrete events in SLAM are usually coded in Subroutine EVENT(IE), where IE is used in a computed GO TO statement to send the program to the correct block of code. Events may occur in "real" time as a result of Subroutine EVENT being called by the model, or specific events may be placed on the event calendar by a call to SCHDL(IEVENT, TIME, A), where IEVENT is the event code, TIME is the time from now the event is to occur, and A is the array holding the attributes to be placed on the event calendar. In this model the Radar Detectin and Visual Detection events schedule themselves to occur every few seconds, simulating continuuing radar and visual search. Other events search Blue aircraft files for available aircraft and assign them to CAPs, and send Red aircraft on low level routes.

Another subroutine which plays a major role in this model is subroutine CMPUTE. This subroutine is called from Subroutine STATE for each airborne aircraft and updates the velocity vector based on the mission code and status flag. In updating the

velocity vector, it does such things as compute intercept vectors, launch missiles, route aircraft home after they reach low fuel state, and execute tactics. All changes to mission codes (after initial assignment by Subroutine EVENT) are made by Subroutine CMPUTE.

Subroutine STATE has already been mentioned. This subroutine is called by SLAM at each event and step time. Thus any variables described by equations in STATE are updated at least every second and possibly more often.

To start the whole simulation, Subroutine INTLC is called. This subroutine initializes all files and common blocks, assigns initial missions, and schedule initial events.

There are several other short supporting subroutines. DOT and CROSS perform the indicated vector operations. LOS returns the Line-of-Sight (LOS) between two points, in vector form. TURN move one vector a specified distance another in the plane formed by the two vectors.

Appendix B

Verification Printout

Part I: Radar Search

Radar Verification Listing

Aircraft Blue 1 is in CAP 1 (Mission Code 111) at time 500.00 as the radar detection subroutine evaluates its relationship to each other airborne aircraft and tests for radar detection. In Figure 4.1a all aircraft are outside detection range (range greater than 270,600 feet) and are not detected.

```
Blue 1,  Mission Code 111,  Speed  585.00 fps,  Time    500.00
Position:  X(1): 10154269.00  X(2): 10183851.00  X(3):   -19987.00
Velocity:  X(1):     .0132     X(2):    1.0962     X(3):     .0000

Red  1  Mission Code 118  Speed  700.00 fps,  Time    500.00
Position:  X(1): 10095600.00  X(2): 10499376.00  X(3):    -1500.00
Velocity:  X(1):    -.0712     X(2):    -.9975     X(3):     .0000
Radar range, Blue 1 to Red  1 is    321465.16 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.30 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   11.22 degrees.
Probability of Radar Detection is  .000. Random number is  .861.
  Red  1 is not detected.
Red  2  Mission Code 118  Speed  700.00 fps,  Time    500.00
Position:  X(1): 10095700.00  X(2): 10500772.00  X(3):    -1700.00
Velocity:  X(1):    -.0712     X(2):    -.9975     X(3):     .0000
Radar range, Blue 1 to Red  2 is    322805.91 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.25 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   11.16 degrees.
Probability of Radar Detection is  .000. Random number is  .368.
  Red  2 is not detected.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    500.00
Position:  X(1): 10095800.00  X(2): 10502168.00  X(3):    -1900.00
Velocity:  X(1):    -.0712     X(2):    -.9975     X(3):     .0000
Radar range, Blue 1 to Red  3 is    324147.31 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.20 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   11.10 degrees.
Probability of Radar Detection is  .000. Random number is  .320.
  Red  3 is not detected.
Red  4  Mission Code 118  Speed  700.00 fps,  Time    500.00
Position:  X(1): 10095900.00  X(2): 10503564.00  X(3):    -2100.00
Velocity:  X(1):    -.0712     X(2):    -.9975     X(3):     .0000
Radar range, Blue 1 to Red  4 is    325489.31 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.15 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   11.04 degrees.
```

```
Probability of Radar Detection is  .000. Random number is  .867.
  Red  4 is not detected.
Red  5 Mission Code 118  Speed  700.00 fps,  Time    500.00
Position:  X(1): 10096000.00  X(2): 10504960.00  X(3):    -2300.00
Velocity:  X(1):    -.0712      X(2):    -.9975     X(3):     .0000
Radar range, Blue 1 to Red  5 is    326831.91 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.10 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.98 degrees.
Probability of Radar Detection is  .000. Random number is  .200.
  Red  5 is not detected.
Red  6 Mission Code 118  Speed  700.00 fps,  Time    500.00
Position:  X(1): 10096100.00  X(2): 10506356.00  X(3):    -2500.00
Velocity:  X(1):    -.0712      X(2):    -.9975     X(3):     .0000
Radar range, Blue 1 to Red  6 is    328175.13 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.05 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.91 degrees.
Probability of Radar Detection is  .000. Random number is  .654.
  Red  6 is not detected.
Red  7 Mission Code 118  Speed  700.00 fps,  Time    500.00
Position:  X(1): 10096200.00  X(2): 10507752.00  X(3):    -2700.00
Velocity:  X(1):    -.0712      X(2):    -.9975     X(3):     .0000
Radar range, Blue 1 to Red  7 is    329518.91 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.01 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.85 degrees.
Probability of Radar Detection is  .000. Random number is  .269.
  Red  7 is not detected.
Red  8 Mission Code 118  Speed  700.00 fps,  Time    500.00
Position:  X(1): 10096300.00  X(2): 10509148.00  X(3):    -2900.00
Velocity:  X(1):    -.0712      X(2):    -.9975     X(3):     .0000
Radar range, Blue 1 to Red  8 is    330863.28 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    2.96 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.79 degrees.
Probability of Radar Detection is  .000. Random number is  .705.
  Red  8 is not detected.
Red  9 Mission Code 114  Speed  850.00 fps,  Time    500.00
Position:  X(1): 10070800.00  X(2): 10495190.00  X(3):   -11408.03
Velocity:  X(1):    -.1415      X(2):    -.9899     X(3):     .0000
Radar range, Blue 1 to Red  9 is    322447.91 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    1.52 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   15.70 degrees.
Probability of Radar Detection is  .000. Random number is  .703.
  Red  9 is not detected.
Red 10 Mission Code 114  Speed  850.00 fps,  Time    500.00
Position:  X(1): 10071726.00  X(2): 10496370.00  X(3):   -11408.03
```

```
Velocity:  X(1):    -.1415      X(2):    -.9899      X(3):      .0000
Radar range, Blue 1 to Red 10 is    323349.75 feet
Radar detection limits are:
  Elevation:  Upper     -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     1.52 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   15.49 degrees.
Probability of Radar Detection is  .000. Random number is  .205.
  Red 10 is not detected.
Red 11  Mission Code 114. Speed  850.00 fps,  Time    500.00
Position:  X(1): 10071640.00  X(2): 10501077.00  X(3):    -14709.26
Velocity:  X(1):    -.1415      X(2):    -.9899      X(3):      .0000
Radar range, Blue 1 to Red 11 is    327853.22 feet
Radar detection limits are:
  Elevation:  Upper     -2.00 degrees, Lower    8.00 degrees.
  Target elevation is      .92 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   15.29 degrees.
Probability of Radar Detection is  .000. Random number is  .333.
  Red 11 is not detected.
Red 12  Mission Code 114  Speed  850.00 fps,  Time    500.00
Position:  X(1): 10072566.00  X(2): 10502257.00  X(3):    -14709.26
Velocity:  X(1):    -.1414      X(2):    -.9899      X(3):      .0000
Radar range, Blue 1 to Red 12 is    328763.78 feet
Radar detection limits are:
  Elevation:  Upper     -2.00 degrees, Lower    8.00 degrees.
  Target elevation is      .92 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   15.08 degrees.
Probability of Radar Detection is  .000. Random number is  .011.
  Red 12 is not detected.
Red 41  Mission Code 114  Speed  850.00 fps,  Time    500.00
Position:  X(1):  9885866.00  X(2): 10609300.00  X(3):    -13026.68
Velocity:  X(1):     .1841      X(2):    -.9829      X(3):      .0000
Radar range, Blue 1 to Red 41 is    503085.94 feet
Radar detection limits are:
  Elevation:  Upper     -2.00 degrees, Lower    8.00 degrees.
  Target elevation is      .79 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   32.94 degrees.
Probability of Radar Detection is  .000. Random number is  .538.
  Red 41 is not detected.
Red 42  Mission Code 114  Speed  850.00 fps,  Time    500.00
Position:  X(1):  9886364.00  X(2): 10610715.00  X(3):    -13026.68
Velocity:  X(1):     .1841      X(2):    -.9829      X(3):      .0000
Radar range, Blue 1 to Red 42 is    504018.25 feet
Radar detection limits are:
  Elevation:  Upper     -2.00 degrees, Lower    8.00 degrees.
  Target elevation is      .79 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   32.80 degrees.
Probability of Radar Detection is  .000. Random number is  .193.
  Red 42 is not detected.
Red 43  Mission Code 114  Speed  850.00 fps,  Time    500.00
Position:  X(1):  9884771.00  X(2): 10615145.00  X(3):    -19337.86
Velocity:  X(1):     .1841      X(2):    -.9829      X(3):      .0000
Radar range, Blue 1 to Red 43 is    508570.66 feet
Radar detection limits are:
  Elevation:  Upper     -2.00 degrees, Lower    8.00 degrees.
```

```
  Target elevation is     .07 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   32.69 degrees.
Probability of Radar Detection is  .000. Random number is  .182.
  Red 43 is not detected.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    500.00
Position:  X(1):  9885339.00  X(2): 10616560.00  X(3):   -19337.86
Velocity:  X(1):     .1843     X(2):   -.9829     X(3):     .0000
Radar range, Blue 1 to Red 44 is    509471.16 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .07 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   32.55 degrees.
Probability of Radar Detection is  .000. Random number is  .605.
  Red 44 is not detected.
```

* Below is a sample of the radar file, with the number of detected radar threats (Nthrt), the call signs, and associated ranges. A call sign of '0' and range of 00' indi cate no target. Therefore, with no detected threats, there are no ranges nor call signs stored. ('Flag = -1' indicates the aircraft is turning outbound in the CAP.)

```
Nthrt Blue( 1) =  0   Time:  500.00,   Flag =  -1,  Msn Code =  111
Threat Call Signs are:  0          0          0          0          0
Threat Ranges are:  999999.00  999999.00  999999.00  999999.00  999999.00
```

Example 1. -Radar Detection

At time 530.00, Blue 1 is outbound in the CAP and all the target aircraft are behind it, so there should be no detections. All the targets are outside the azimuth limits and are not detected.

```
Blue 1,  Mission Code 111,  Speed  585.00 fps,  Time    530.00
Position:  X(1): 10163438.00  X(2): 10179195.00  X(3):   -19987.00
Velocity:  X(1):     .1326     X(2):   -.9912     X(3):     .0000
Red  1  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094100.00  X(2): 10478436.00  X(3):    -1500.00
Velocity:  X(1):    -.0712     X(2):   -.9975     X(3):     .0000
Radar range, Blue 1 to Red  1 is    307725.06 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.44 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.59 degrees.
Red  2  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094200.00  X(2): 10479832.00  X(3):    -1700.00
Velocity:  X(1):    -.0712     X(2):   -.9975     X(3):     .0000
```

```
Radar range, Blue 1 to Red  2 is    309048.41 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.39 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.66 degrees.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094300.00  X(2): 10481228.00  X(3):    -1900.00
Velocity:  X(1):   -.0712      X(2):   -.9975     X(3):    .0000
Radar range, Blue 1 to Red  3 is    310372.56 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.34 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.74 degrees.
Red  4  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094400.00  X(2): 10482624.00  X(3):    -2100.00
Velocity:  X(1):   -.0712      X(2):   -.9975     X(3):    .0000
Radar range, Blue 1 to Red  4 is    311697.53 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.29 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.81 degrees.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094500.00  X(2): 10484020.00  X(3):    -2300.00
Velocity:  X(1):   -.0712      X(2):   -.9975     X(3):    .0000
Radar range, Blue 1 to Red  5 is    313023.25 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.24 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.89 degrees.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094600.00  X(2): 10485416.00  X(3):    -2500.00
Velocity:  X(1):   -.0712      X(2):   -.9975     X(3):    .0000
Radar range, Blue 1 to Red  6 is    314349.75 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.19 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  174.96 degrees.
Red  7  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094700.00  X(2): 10486812.00  X(3):    -2700.00
Velocity:  X(1):   -.0712      X(2):   -.9975     X(3):    .0000
Radar range, Blue 1 to Red  7 is    315677.00 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.14 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  175.04 degrees.
Red  8  Mission Code 118  Speed  700.00 fps,  Time    530.00
Position:  X(1): 10094800.00  X(2): 10488208.00  X(3):    -2900.00
Velocity:  X(1):   -.0712      X(2):   -.9975     X(3):    .0000
Radar range, Blue 1 to Red  8 is    317005.00 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.09 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  175.11 degrees.
Red  9  Mission Code 114  Speed  850.00 fps,  Time    530.00
```

```
Position: X(1): 10067200.00 X(2): 10469960.00 X(3):   -11408.03
Velocity: X(1):   -.1416    X(2):   -.9899    X(3):    .0000
Radar range, Blue 1 to Red  9 is    306397.84 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
        elev  ation is    1.60 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  169.32 degrees.
Red 10  Mission Code 114  Speed  850.00 fps,  Time    530.00
Position: X(1): 10068126.00 X(2): 10471140.00 X(3):   -11408.03
Velocity: X(1):   -.1416    X(2):   -.9899    X(3):    .0000
Radar range, Blue 1 to Red 10 is    307229.34 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    1.60 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  169.55 degrees.
Red 11  Mission Code 114  Speed  850.00 fps,  Time    530.00
Position: X(1): 10068040.00 X(2): 10475847.00 X(3):   -14709.26
Velocity: X(1):   -.1415    X(2):   -.9899    X(3):    .0000
Radar range, Blue 1 to Red 11 is    311658.53 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .97 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  169.80 degrees.
Red 12  Mission Code 114  Speed  850.00 fps,  Time    530.00
Position: X(1): 10068966.00 X(2): 10477027.00 X(3):   -14709.26
Velocity: X(1):   -.1414    X(2):   -.9899    X(3):    .0000
Radar range, Blue 1 to Red 12 is    312500.75 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .97 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  170.03 degrees.
Red 41  Mission Code 114  Speed  850.00 fps,  Time    530.00
Position: X(1):  9890558.00 X(2): 10584250.00 X(3):   -13026.68
):          .18      41     X(2):   -.9829    X(3):    .0000
Radar range, Blue 1 to Red 41 is    488448.06 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .82 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  153.66 degrees.
Red 42  Mission Code 114  Speed  850.00 fps,  Time    530.00
Position: X(1):  9891056.00 X(2): 10585665.00 X(3):   -13026.68
Velocity: X(1):    .1841    X(2):   -.9829    X(3):    .0000
Radar range, Blue 1 to Red 42 is    489344.75 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .82 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  153.80 degrees.
Red 43  Mission Code 114  Speed  850.00 fps,  Time    530.00
Position: X(1):  9889463.00 X(2): 10590095.00 X(3):   -19337.86
Velocity: X(1):    .1841    X(2):   -.9829    X(3):    .0000
Radar range, Blue 1 to Red 43 is    493863.88 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .08 degrees.
```

```
Azimuth limits are: +/-  55.00 degrees. Target azimuth  153.94 degrees.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    530.00
Position:  X(1):  9890049.00  X(2): 10591510.00  X(3):    -19337.86
Velocity:  X(1):     .1843     X(2):   -.9829     X(3):     .0000
Radar range, Blue 1 to Red 44 is     494717.72 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is      .08 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth  154.08 degrees.
```

* As expected, the radar file shows no detected threats.
The 'Flag = -2' indicates the aircraft is outbound in the CAP.

```
Nthrt Blue(1) =    0    Time:    530.00     Flag =  -2,  Msn Code =  111
Threat Call Signs are:   0           0           0           0           0
Threat Ranges are:  999999.00  999999.00  999999.00  999999.00  999999.00
```

Example 2. Radar Detection

At time 675.00 Blue 1 is headed back inbound to the CAP point. All the targets are still out of range, even though they are within the angular limits of the radar search. As Blue 1 gets closer to the targets, first one and then more of them are detected. Note that the same ones are not detected on every sweep until fairly close range. The actual radar operates in the same manner.

```
Blue 1,  Mission Code 111,  Speed  585.00 fps,  Time    675.00
Position:  X(1): 10163168.00  X(2): 10117175.00  X(3):    -20000.04
Velocity:  X(1):    -.1322     X(2):     .9912     X(3):     .0000
Red  1  Mission Code 118  Speed  700.00 fps,  Time    675.00
Position:  X(1): 10077422.00  X(2): 10378993.00  X(3):     -1500.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  1 is    276121.88 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.84 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.54 degrees.
Probability of Radar Detection is  .000. Random number is  .560.
  Red  1 is not detected.
Red  2  Mission Code 118  Speed  700.00 fps,  Time    675.00
Position:  X(1): 10077898.00  X(2): 10380309.00  X(3):     -1700.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  2 is    277209.97 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
```

```
  Target elevation is    3.79 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.36 degrees.
Probability of Radar Detection is  .000. Random number is  .627.
  Red  2 is not detected.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    675.00
Position:  X(1): 10078374.00  X(2): 10381625.00  X(3):     -1900.00
Velocity:  X(1):    -.3396     X(2):   -.9406     X(3):     .0000
Radar range, Blue 1 to Red  3 is    278300.97 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.73 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.18 degrees.
Probability of Radar Detection is  .000. Random number is  .574.
  Red  3 is not detected.
Red  4  Mission Code 118  Speed  700.00 fps,  Time    675.00
Position:  X(1): 10078850.00  X(2): 10382941.00  X(3):     -2100.00
Velocity:  X(1):    -.3396     X(2):   -.9406     X(3):     .0000
Radar range, Blue 1 to Red  4 is    279394.88 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.67 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   10.00 degrees.
Probability of Radar Detection is  .000. Random number is  .068.
  Red  4 is not detected.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    675.00
Position:  X(1): 10079326.00  X(2): 10384257.00  X(3):     -2300.00
Velocity:  X(1):    -.3396     X(2):   -.9406     X(3):     .0000
Radar range, Blue 1 to Red  5 is    280491.66 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.62 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    9.83 degrees.
Probability of Radar Detection is  .000. Random number is  .455.
  Red  5 is not detected.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    675.00
Position:  X(1): 10079802.00  X(2): 10385573.00  X(3):     -2500.00
Velocity:  X(1):    -.3396     X(2):   -.9406     X(3):     .0000
Radar range, Blue 1 to Red  6 is    281591.22 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.56 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    9.66 degrees.
Probability of Radar Detection is  .000. Random number is  .084.
  Red  6 is not detected.
Red  7  Mission Code 118  Speed  700.00 fps,  Time    675.00
Position:  X(1): 10080278.00  X(2): 10386889.00  X(3):     -2700.00
Velocity:  X(1):    -.3396     X(2):   -.9406     X(3):     .0000
Radar range, Blue 1 to Red  7 is    282693.63 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.51 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    9.48 degrees.
Probability of Radar Detection is  .000. Random number is  .774.
  Red  7 is not detected.
```

```
Red  8  Mission Code 118  Speed  700.00 fps,  Time    675.00
Position:  X(1): 10080754.00  X(2): 10388205.00  X(3):     -2900.00
Velocity:  X(1):    -.3396      X(2):    -.9406      X(3):     .0000
Radar range, Blue 1 to Red  8 is    283798.78 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.45 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    9.31 degrees.
Probability of Radar Detection is  .000. Random number is  .012.
  Red  8 is not detected.
Red  9  Mission Code 114  Speed  850.00 fps,  Time    675.00
Position:  X(1): 10049800.00  X(2): 10348015.00  X(3):    -11408.03
Velocity:  X(1):    -.1417      X(2):    -.9899      X(3):     .0000
Radar range, Blue 1 to Red  9 is    257319.33 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    1.91 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   18.56 degrees.
Probability of Radar Detection is  .106. Random number is  .532.
  Red  9 is not detected.
Red 10  Mission Code 114  Speed  850.00 fps,  Time    675.00
Position:  X(1): 10050726.00  X(2): 10349195.00  X(3):    -11408.03
Velocity:  X(1):    -.1417      X(2):    -.9899      X(3):     .0000
Radar range, Blue 1 to Red 10 is    257973.47 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    1.91 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   18.26 degrees.
Probability of Radar Detection is  .100. Random number is  .734.
  Red 10 is not detected.
Red 11  Mission Code 114  Speed  850.00 fps,  Time    675.00
Position:  X(1): 10050640.00  X(2): 10353902.00  X(3):    -14709.26
Velocity:  X(1):    -.1416      X(2):    -.9899      X(3):     .0000
Radar range, Blue 1 to Red 11 is    262164.47 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    1.16 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   17.83 degrees.
Probability of Radar Detection is  .065. Random number is  .375.
  Red 11 is not detected.
Red 12  Mission Code 114  Speed  850.00 fps,  Time    675.00
Position:  X(1): 10051566.00  X(2): 10355082.00  X(3)'   -14709.26
Velocity:  X(1):    -.1414      X(2):    -.9899      X(3):     .0000
Radar range, Blue 1 to Red 12 is    262835.97 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    1.15 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   17.53 degrees.
Probability of Radar Detection is  .060. Random number is  .923.
  Red 12 is not detected.
Red 41  Mission Code 114  Speed  850.00 fps,  Time    675.00
Position:  X(1):   9913238.00  X(2): 10463175.00  X(3):    -13026.68
Velocity:  X(1):     .1841      X(2):    -.9829      X(3):     .0000
Radar range, Blue 1 to Red 41 is    426883.63 feet
```

```
Radar detection limits are:
  Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .94 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   28.24 degrees.
Probability of Radar Detection is  .000. Random number is  .464.
  Red 41 is not detected.
Red 42  Mission Code 114  Speed  850.00 fps,  Time    675.00
Position:  X(1):  9913736.00  X(2): 10464590.00  X(3):   -13026.68
Velocity:  X(1):     .1841     X(2):    -.9829     X(3):     .0000
Radar range, Blue 1 to Red 42 is    427740.75 feet
Radar detection limits are:
  Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .93 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   28.08 degrees.
Probability of Radar Detection is  .000. Random number is  .311.
  Red 42 is not detected.
Red 43  Mission Code 114  Speed  850.00 fps,  Time    675.00
Position:  X(1):  9912143.00  X(2): 10469020.00  X(3):   -19337.86
Velocity:  X(1):     .1841     X(2):    -.9829     X(3):     .0000
Radar range, Blue 1 to Red 43 is    432213.97 feet
Radar detection limits are:
  Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .09 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   27.91 degrees.
Probability of Radar Detection is  .000. Random number is  .030.
  Red 43 is not detected.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    675.00
Position:  X(1):  9912814.00  X(2): 10470435.00  X(3):   -19337.86
Velocity:  X(1):     .1843     X(2):    -.9829     X(3):     .0000
Radar range, Blue 1 to Red 44 is    432978.28 feet
Radar detection limits are:
  Elevation: Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .09 degrees.
         /-  5      5.00        degre es. Target azimuth   27.73 degrees.
Probability of Radar Detection is  .000. Random number is  .855.
  Red 44 is not detected.

Nthrt Blue(1) =    0    Time:     675.00     Flag =    2,  Msn Code =  111
      e:          0                 0          0          0          0
Threat Ranges are:  999999.00   999999.00   999999.00   999999.00   999999.00

Nthrt Blue(1) =    1    Time:     690.00     Flag =    2,  Msn Code =  111
Threat Call Signs are:   1          0          0          0          0
Threat Ranges are:  259391.98   999999.00   999999.00   999999.00   999999.00

Nthrt Blue(1) =    2    Time:     695.00     Flag =    2,  Msn Code =  111
Threat Call Signs are:  10         11          0          0          0
Threat Ranges are:  233161.16   237226.98   999999.00   999999.00   999999.00

Nthrt Blue(1) =    3    Time:     700.00     Flag =    2,  Msn Code =  111
Threat Call Signs are:   9         11          7          0          0
Threat Ranges are:  226536.91   230248.92   254679.70   999999.00   999999.00

Nthrt Blue(1) =    3    Time:     705.00     Flag =    2,  Msn Code =  111
```

```
Threat Call Signs are:   9         2         7         0         0
Threat Ranges are:  220552.22  243979.89  249168.13  999999.00  999999.00

Nthrt Blue(1) =   4    Time:    710.00     Flag =   2,  Msn Code =  111
Threat Call Signs are:   9        10         4         6         0
Threat Ranges are:  214636.09  215140.80  240602.84  242658.27  999999.00

Nthrt Blue(1) =   5    Time:    715.00     Flag =   2,  Msn Code =  111
Threat Call Signs are:  -9        10        11         6         8
Threat Ranges are:  208794.33  209272.11  210295.05  237231.84  239278.33

Nthrt Blue(1) =   5    Time:    720.00     Flag =   2,  Msn Code =  111
Threat Call Signs are:   9         3         4         6         8
Threat Ranges are:  203033.36  228847.50  229842.81  231846.48  233867.16

Nthrt Blue(1) =   7    Time:    725.00     Flag =   2,  Msn Code =  111
Threat Call Signs are:  12        11         9         1         5
Threat Ranges are:  195998.63  196416.89  197360.27  221601.33  225515.16
```

Example 3. Radar Detection

At a range of less than 200,000 feet the fighter is released from the CAP and begins an intercept and attack on the closest target. A Mission Code of 120 and a "Flag = 1" indicates the fighter is running an intercept but is not locked on to a target, so the radar is still searching. The radar scan pattern is oriented along the line of sight from the fighter to the nearest target, as indicated by the changed elevation limits.

```
Blue   1 committed from CAP  1, Time:  726.00
Blue 1,  Mission Code 120,  Speed  610.00 fps,  Time    730.00
Position:  X(1): 10157900.00  X(2): 10148818.00  X(3):    -19930.11
Velocity:  X(1):    -.4728     X(2):     .8808     X(3):     .0233
Red  1  Mission Code 118  Speed  700.00 fps,  Time    730.00
Position:  X(1): 10064332.00  X(2): 10342803.00  X(3):    -1500.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  1 is    216159.25 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
  Target elevation is    3.55 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    2.48 degrees.
Probability of Radar Detection is  .449. Random number is  .786.
  Red  1 is not detected.
  Code        118         Spee d  700.00 fps,  Time    730.00
Position:  X(1): 10064808.00  X(2): 1034.119.00  X(3):    -1700.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):     .0000
```

```
Radar range, Blue 1 to Red  2 is    217119.64 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
  Target elevation is    3.48 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    2.74 degrees.
Probability of Radar Detection is  .441. Random number is  .749.
  Red  2 is not detected.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    730.00
Position:  X(1): 10065284.00  X(2): 10345435.00  X(3):    -1900.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  3 is    218084.97 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
  Target elevation is    3.40 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    3.00 degrees.
Probability of Radar Detection is  .433. Random number is  .641.
  Red  3 is not detected.
Red  4  Mission Code 118  Speed  700.00 fps,  Time    730.00
Position:  X(1): 10065760.00  X(2): 10346751.00  X(3):    -2100.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  4 is    219055.16 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
  Target elevation is    3.33 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    3.26 degrees.
Probability of Radar Detection is  .425. Random number is  .745.
  Red  4 is not detected.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    730.00
Position:  X(1): 10066236.00  X(2): 10348067.00  X(3):    -2300.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  5 is    220030.17 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
  Target elevation is    3.26 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    3.52 degrees.
Probability of Radar Detection is  .416. Random number is  .785.
  Red  5 is not detected.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    730.00
Position:  X(1): 10066712.00  X(2): 10349383.00  X(3):    -2500.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  6 is    221009.91 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
  Target elevation is    3.18 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    3.78 degrees.
Probability of Radar Detection is  .408. Random number is  .527.
  Red  6 is not detected.
Red  7  Mission Code 118  Speed  700.00 fps,  Time    730.00
Position:  X(1): 10067188.00  X(2): 10350699.00  X(3):    -2700.00
Velocity:  X(1):   -.3396     X(2):   -.9406     X(3):    .0000
Radar range, Blue 1 to Red  7 is    221994.33 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
  Target elevation is    3.11 degrees.
```

Azimuth limits are: +/- 55.00 degrees. Target azimuth 4.03 degrees.
Probability of Radar Detection is .400. Random number is .681.
Red 7 is not detected.
Red 8 Mission Code 118 Speed 700.00 fps, Time 730.00
Position: X(1): 10067664.00 X(2): 10352015.00 X(3): -2900.00
Velocity: X(1): -.3396 X(2): -.9406 X(3): .0000
Radar range, Blue 1 to Red 8 is 222983.36 feet
Radar detection limits are:
Elevation: Upper -5.96 degrees, Lower 6.04 degrees.
Target elevation is 3.04 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 4.28 degrees.
Probability of Radar Detection is .392. Random number is .768.
Red 8 is not detected.
Red 9 Mission Code 114 Speed 850.00 fps, Time 730.00
Position: X(1): 10043200.00 X(2): 10301760.00 X(3): -11408.03
Velocity: X(1): -.1417 X(2): -.9899 X(3): .0000
Radar range, Blue 1 to Red 9 is 191363.45 feet
Radar detection limits are:
Elevation: Upper -5.96 degrees, Lower 6.04 degrees.
Target elevation is 1.22 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 8.64 degrees.
Probability of Radar Detection is .655. Random number is .627.
Red 9 is detected.
Red 10 Mission Code 114 Speed 850.00 fps, Time 730.00
Position: X(1): 10044126.00 X(2): 10302940.00 X(3): -11408.03
Velocity: X(1): -.1417 X(2): -.9899 X(3): .0000
Radar range, Blue 1 to Red 10 is 191756.98 feet
Radar detection limits are:
Elevation: Upper -5.96 degrees, Lower 6.04 degrees.
Target elevation is 1.21 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 8.21 degrees.
Probability of Radar Detection is .652. Random number is .785.
Red 10 is not detected.
Red 11 Mission Code 114 Speed 850.00 fps, Time 730.00
Position: X(1): 10060232.00 X(2): 10310758.00 X(3): -15309.75
Velocity: X(1): .5163 X(2): -.8561 X(3): -.0244
Radar range, Blue 1 to Red 11 is 189169.11 feet
Radar detection limits are:
Elevation: Upper -5.96 degrees, Lower 6.04 degrees.
Target elevation is .06 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 2.87 degrees.
Probability of Radar Detection is .674. Random number is .121.
Red 11 is detected.
Red 12 Mission Code 114 Speed 850.00 fps, Time 730.00
Position: X(1): 10063848.00 X(2): 10312403.00 X(3): -15406.52
Velocity: X(1): .5163 X(2): -.8561 X(3): -.0244
Radar range, Blue 1 to Red 12 is 188749.30 feet
Radar detection limits are:
Elevation: Upper -5.96 degrees, Lower 6.04 degrees.
Target elevation is .04 degrees.
Azimuth limits are: +/- 55.00 degrees. Target azimuth 1.67 degrees.
Probability of Radar Detection is .677. Random number is .938.
Red 12 is not detected.
Red 41 Mission Code 114 Speed 850.00 fps, Time 730.00

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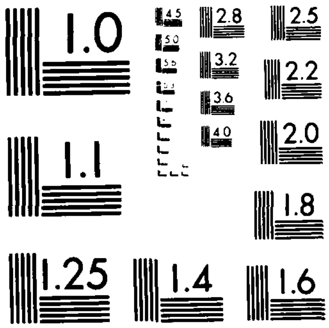

MICROCOPY RESOLUTION TEST CHART
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```
Position:  X(1):  9921841.00  X(2): 10417250.00  X(3):   -13026.68
Velocity:  X(1):     .1841    X(2):   -.9829     X(3):     .0000
Radar range, Blue 1 to Red 41 is    357529.38 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
  Target elevation is    -.23 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   13.10 degrees.
Probability of Radar Detection is  .000. Random number is  .617.
  Red 41 is not detected.
Red 42  Mission Code 114  Speed  850.00 fps,  Time    730.00
Position:  X(1):  9922339.00  X(2): 10419665.00  X(3):   -13026.68
Velocity:  X(1):     .1841    X(2):   -.9829     X(3):     .0000
Radar range, Blue 1 to Red 42 is    358265.34 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
  Target elevation is    -.23 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   12.89 degrees.
Probability of Radar Detection is  .000. Random number is  .756.
  Red 42 is not detected.
Red 43  Mission Code 114  Speed  850.00 fps,  Time    730.00
Position:  X(1):  9920746.00  X(2): 10423095.00  X(3):   -19337.86
Velocity:  X(1):     .1841    X(2):   -.9829     X(3):     .0000
Radar range, Blue 1 to Red 43 is    362588.25 feet
Radar detection limits are:
  Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
  Target elevation is   -1.24 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   12.62 degrees.
Probability of Radar Detection is  .000. Random number is  .922.
  Red 43 is not detected.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    730.00
Position:  X(1):  9921449.00  X(2): 10424510.00  X(3):   -19337.86
Velocity:  X(1):     .1843    X(2):   -.9829     X(3):     .0000
Radar range, Blue 1 to Red 44 is    363201.75 feet
Radar detection limits are:
Elevation:  Upper    -5.96 degrees, Lower    6.04 degrees.
Target elevation is   -1.24 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   12.39 degrees.
Probability of Radar Detection is  .000. Random number is  .014.
  Red 44 is not detected.

Nthrt Blue(1) =    2    Time:     730.00     Flag =    1,  Msn Code =  120
Threat Call Signs are:  11          9           0           0           0
Threat Ranges are:  189169.11  191363.45  999999.00  999999.00  999999.00
```

Example 4. Radar Detection

In Example 4 above, none of the low targets were detected because of a run of 'high' random numbers. In turning to an intercept heading for Red 11, the fighter put all the targets just outside the limits of the radar,

as will be seen in the following figure, and no targets are detected on the next radar sweep. This causes the fighter to be reassigned to the CAP (Mission Code 111).

```
Blue 1, Mission Code 120, Speed 635.00 fps, Time    735.00
Position: X(1): 10155098.00 X(2): 10148996.00 X(3):    -19828.59
Velocity: X(1):    -.9931     X(2):    -.1117     X(3):     .0348
Red  1 Mission Code 118 Speed 700.00 fps, Time    735.00
Position: X(1): 10063142.00 X(2): 10339513.00 X(3):    -1500.00
Velocity: X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  1 is    212340.70 feet
Radar detection limits are:
  Elevation: Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    2.95 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   70.65 degrees.
Red  2 Mission Code 118 Speed 700.00 fps, Time    735.00
Position: X(1): 10063618.00 X(2): 10340829.00 X(3):    -1700.00
Velocity: X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  2 is    213300.58 feet
Radar detection limits are:
  Elevation: Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    2.88 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   70.92 degrees.
Red  3 Mission Code 118 Speed 700.00 fps, Time    735.00
Position: X(1): 10064094.00 X(2): 10342145.00 X(3):    -1900.00
Velocity: X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  3 is    214265.48 feet
Radar detection limits are:
  Elevation: Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    2.80 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   71.19 degrees.
Red  4 Mission Code 118 Speed 700.00 fps, Time    735.00
Position: X(1): 10064570.00 X(2): 10343461.00 X(3):    -2100.00
Velocity: X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  4 is    215235.34 feet
Radar detection limits are:
  Elevation: Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    2.73 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   71.46 degrees.
Red  5 Mission Code 118 Speed 700.00 fps, Time    735.00
Position: X(1): 10065046.00 X(2): 10344777.00 X(3):    -2300.00
Velocity: X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  5 is    216210.13 feet
Radar detection limits are:
  Elevation: Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    2.65 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   71.72 degrees.
Red  6 Mission Code 118 Speed 700.00 fps, Time    735.00
Position: X(1): 10065522.00 X(2): 10346093.00 X(3):    -2500.00
Velocity: X(1):    -.3396     X(2):    -.9406     X(3):     .0000
```

```
Radar range, Blue 1 to Red  6 is    217189.70 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    2.58 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   71.98 degrees.
Red  7  Mission Code 118  Speed  700.00 fps,  Time    735.00
Position:  X(1): 10065998.00  X(2): 10347409.00  X(3):    -2700.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  7 is    218174.05 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    2.51 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   72.24 degrees.
Red  8  Mission Code 118  Speed  700.00 fps,  Time    735.00
Position:  X(1): 10066474.00  X(2): 10348725.00  X(3):    -2900.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  8 is    219163.09 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    2.43 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   72.49 degrees.
Red  9  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1): 10042600.00  X(2): 10297555.00  X(3):   -11408.03
Velocity:  X(1):    -.1417     X(2):    -.9899     X(3):     .0000
Radar range, Blue 1 to Red  9 is    186538.16 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is     .59 degrees.
      /-  5       5.00        degre es. Target azimuth   59.28 degrees.
Red 10  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1): 10043526.00  X(2): 10298735.00  X(3):   -11408.03
Velocity:  X(1):    -.1417     X(2):    -.9899     X(3):     .0000
Radar range, Blue 1 to Red 10 is    186925.08 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is     .59 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   59.73 degrees.
Red 11  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1): 10059422.00  X(2): 10306588.00  X(3):   -15309.75
Velocity:  X(1):    -.1903     X(2):    -.9817     X(3):     .0000
Radar range, Blue 1 to Red 11 is    184416.80 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    -.59 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   65.16 degrees.
Red 12  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1): 10066043.00  X(2): 10308763.00  X(3):   -15510.33
Velocity:  X(1):     .5163     X(2):    -.8561     X(3):    -.0244
Radar range, Blue 1 to Red 12 is    182961.56 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    -.64 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   67.28 degrees.
Red 41  Mission Code 114  Speed  850.00 fps,  Time    735.00
```

```
Position:  X(1):  9922623.00  X(2): 10413075.00  X(3):   -13026.68
Velocity:  X(1):     .1841     X(2):    -.9829     X(3):     .0000
Radar range, Blue 1 to Red 41 is    351892.91 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    -.89 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   55.06 degrees.
Red 42  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1):  9923121.00  X(2): 10414490.00  X(3):   -13026.68
Velocity:  X(1):     .1841     X(2):    -.9829     X(3):     .0000
Radar range, Blue 1 to Red 42 is    352628.22 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is    -.89 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   55.27 degrees.
Red 43  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1):  9921528.00  X(2): 10418920.00  X(3):   -19337.86
Velocity:  X(1):     .1841     X(2):    -.9829     X(3):     .0000
Radar range, Blue 1 to Red 43 is    356951.19 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is   -1.91 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   55.55 degrees.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    735.00
Position:  X(1):  9922234.00  X(2): 10420335.00  X(3):   -19337.86
Velocity:  X(1):     .1843     X(2):    -.9829     X(3):     .0000
Radar range, Blue 1 to Red 44 is    357562.22 feet
Radar detection limits are:
  Elevation:  Upper    -6.59 degrees, Lower    5.41 degrees.
  Target elevation is   -1.91 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   55.78 degrees.

Nthrt Blue(1) =    0    Time:     735.00     Flag =    1,  Msn Code =  120
Threat Call Signs are:   0           0           0           0           0
Threat Ranges are:  999999.00  999999.00  999999.00  999999.00  999999.00
```

Example 5. Radar Detection

In turning back to the CAP, the fighter detects the targets again and begins another intercept, as seen in Example 6:

```
Blue 1,  Mission Code 111,  Speed  610.00 fps,  Time    740.00
Position:  X(1): 10152160.00  X(2): 10149805.00  X(3):   -19732.22
Velocity:  X(1):    -.8631     X(2):     .5044     X(3):     .0268
Red  1  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10061952.00  X(2): 10336223.00  X(3):    -1500.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):     .0000
Radar range, Blue 1 to Red  1 is    207897.98 feet
Radar detection limits are:
```

```
   Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    3.49 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   33.88 degrees.
Probability of Radar Detection is  .518. Random number is  .962.
  Red  1 is not detected.
Red  2  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10062428.00  X(2): 10337539.00  X(3):    -1700.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  2 is    208856.53 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.41 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   34.15 degrees.
Probability of Radar Detection is  .510. Random number is  .231.
  Red  2   is   detected.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10062904.00  X(2): 10338855.00  X(3):    -1900.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  3 is    209820.22 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.34 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   34.43 degrees.
Probability of Radar Detection is  .501. Random number is  .126.
  Red  3   is   detected.
Red  4  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10063380.00  X(2): 10340171.00  X(3):    -2100.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  4 is    210788.98 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.26 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   34.70 degrees.
Probability of Radar Detection is  .493. Random number is  .407.
  Red  4   is   detected.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10063856.00  X(2): 10341487.00  X(3):    -2300.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  5 is    211762.77 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.18 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   34.97 degrees.
Probability of Radar Detection is  .485. Random number is  .001.
  Red  5   is   detected.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    740.00
Position:  X(1): 10064332.00  X(2): 10342803.00  X(3):    -2500.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  6 is    212741.48 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.11 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   35.23 degrees.
Probability of Radar Detection is  .477. Random number is  .709.
```

```
  Red  6 is not detected.
 Red  7  Mission Code 118  Speed  700.00 fps,  Time    740.00
 Position:  X(1): 10064808.00  X(2): 10344119.00  X(3):    -2700.00
 Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
 Radar range, Blue 1 to Red  7 is    213725.06 feet
 Radar detection limits are:
   Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    3.03 degrees.
 Azimuth limits are: +/- -55.00 degrees. Target azimuth   35.49 degrees.
 Probability of Radar Detection is  .469. Random number is  .013.
   Red  7   is   detected.
 Red  8  Mission Code 118  Speed  700.00 fps,  Time    740.00
 Position:  X(1): 10065284.00  X(2): 10345435.00  X(3):    -2900.00
 Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
 Radar range, Blue 1 to Red  8 is    214713.45 feet
 Radar detection limits are:
   Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    2.96 degrees.
 Azimuth limits are: +/-  55.00 degrees. Target azimuth   35.76 degrees.
 Probability of Radar Detection is  .461. Random number is  .266.
   Red  8   is   detected.
 Red  9  Mission Code 114  Speed  850.00 fps,  Time    740.00
 Position:  X(1): 10042000.00  X(2): 10293350.00  X(3):   -11408.03
 Velocity:  X(1):    -.1417     X(2):    -.9899     X(3):    .0000
 Radar range, Blue 1 to Red  9 is    181134.44 feet
 Radar detection limits are:
   Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    1.10 degrees.
 Azimuth limits are: +/-  55.00 degrees. Target azimuth   22.20 degrees.
 Probability of Radar Detection is  .741. Random number is  .148.
   Red  9   is   detected.
 Red 10  Mission Code 114  Speed  850.00 fps,  Time    740.00
 Position:  X(1): 10042926.00  X(2): 10294530.00  X(3):   -11408.03
 Velocity:  X(1):    -.1417     X(2):    -.9899     X(3):    .0000
 Radar range, Blue 1 to Red 10 is    181512.22 feet
 Radar detection limits are:
   Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    1.09 degrees.
 Azimuth limits are: +/-  55.00 degrees. Target azimuth   22.66 degrees.
 Probability of Radar Detection is  .737. Random number is  .467.
   Red 10   is   detected.
 Red 11  Mission Code 114  Speed  850.00 fps,  Time    740.00
 Position:  X(1): 10058612.00  X(2): 10302418.00  X(3):   -15309.75
 Velocity:  X(1):    -.1903     X(2):    -.9817     X(3):    .0000
 Radar range, Blue 1 to Red 11 is    179057.30 feet
 Radar detection limits are:
   Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
   Target elevation is    -.12 degrees.
 Azimuth limits are: +/-  55.00 degrees. Target azimuth   28.19 degrees.
 Probability of Radar Detection is  .758. Random number is  .712.
   Red 11   is   detected.
 Red 12  Mission Code 114  Speed  850.00 fps,  Time    740.00
 Position:  X(1): 10068238.00  X(2): 10305123.00  X(3):   -15614.13
 Velocity:  X(1):     .5163     X(2):    -.8561     X(3):   -.0244
```

```
Radar range, Blue 1 to Red 12 is    176588.63 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    -.20 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   31.32 degrees.
Probability of Radar Detection is  .778. Random number is  .687.
  Red 12   is   detected.
Red 41  Mission Code 114  Speed  850.00 fps,  Time    740.00
Position:  X(1):  9923405.00  X(2): 10408900.00  X(3):   -13026.68
Velocity:  X(1):    .1841     X(2):   -.9829     X(3):    .0000
Radar range, Blue 1 to Red 41 is    345693.56 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    -.42 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   18.26 degrees.
Probability of Radar Detection is  .000. Random number is  .284.
  Red 41 is not detected.
Red 42  Mission Code 114  Speed  850.00 fps,  Time    740.00
Position:  X(1):  9923903.00  X(2): 10410315.00  X(3):   -13026.68
Velocity:  X(1):    .1841     X(2):   -.9829     X(3):    .0000
Radar range, Blue 1 to Red 42 is    346427.03 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    -.43 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   18.47 degrees.
Probability of Radar Detection is  .000. Random number is  .610.
  Red 42 is not detected.
Red 43  Mission Code 114  Speed  850.00 fps,  Time    740.00
Position:  X(1):  9922310.00  X(2): 10414745.00  X(3):   -19337.86
Velocity:  X(1):    .1841     X(2):   -.9829     X(3):    .0000
Radar range, Blue 1 to Red 43 is    350748.31 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   -1.47 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   18.76 degrees.
Probability of Radar Detection is  .000. Random number is  .392.
  Red 43 is not detected.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    740.00
Position:  X(1):  9923019.00  X(2): 10416160.00  X(3):   -19337.86
Velocity:  X(1):    .1843     X(2):   -.9829     X(3):    .0000
Radar range, Blue 1 to Red 44 is    351355.59 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   -1.47 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   18.99 degrees.
Probability of Radar Detection is  .000. Random number is  .241.
  Red 44 is not detected.
Nthrt Blue(1) =  10    Time:    740.00     Flag =   1,  Msn Code =  111
Threat Call Signs are:  12          11          9          10          2
Threat Ranges are:  176588.63  179057.30  181134.44  181512.22  208856.53
```

Example 6. Radar Detection

Picking up the intercept, the fighter will continue it until reaching lock-on range of 90,000 feet (15 Nautical Miles). The pilot normally does this to get as much information as possible about the tactical situation in front of him. As soon as he locks on, the radar begins tracking a single target and he gets no information about any other targets.

```
Blue   1 committed from CAP  1, Time:  741.00
Blue 1,  Mission Code 120,  Speed  635.00 fps,  Time    745.00
Position:  X(1): 10150856.00  X(2): 10152644.00  X(3):   -19664.34
Velocity:  X(1):    -.4182     X(2):     .9081     X(3):    .0217
Red  1  Mission Code 118  Speed  700.00 fps,  Time    745.00
Position:  X(1): 10060762.00  X(2): 10332933.00  X(3):    -1500.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  1 is    202363.53 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    3.90 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    1.83 degrees.
Probability of Radar Detection is  .564. Random number is  .508.
  Red  1   is   detected.
Red  2  Mission Code 118  Speed  700.00 fps,  Time    745.00
Position:  X(1): 10061238.00  X(2): 10334249.00  X(3):    -1700.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  2 is    203308.83 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    3.82 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    1.54 degrees.
Probability of Radar Detection is  .556. Random number is  .465.
  Red  2   is   detected.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    745.00
Position:  X(1): 10061714.00  X(2): 10335565.00  X(3):    -1900.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  3 is    204259.55 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    3.74 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    1.26 degrees.
Probability of Radar Detection is  .548. Random number is  .535.
  Red  3   is   detected.
Red  4  Mission Code 118  Speed  700.00 fps,  Time    745.00
Position:  X(1): 10062190.00  X(2): 10336881.00  X(3):    -2100.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  4 is    205215.59 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    3.66 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth     .97 degrees.
```

```
Probability of Radar Detection is  .540. Rancom number is  .316.
  Red  4   is   detected.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    745.00
Position:  X(1): 10062666.00  X(2): 10338197.00  X(3):    -2300.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  5 is    206176.89 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    3.58 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth     .69 degrees.
Probability of Radar Detection is  .532. Random number is  .624.
  Red  5 is not detected.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    745.00
Position:  X(1): 10063142.00  X(2): 10339513.00  X(3):    -2500.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  6 is    207143.39 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    3.50 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth     .42 degrees.
Probability of Radar Detection is  .524. Random number is  .856.
  Red  6 is not detected.
Red  7  Mission Code 118  Speed  700.00 fps,  Time    745.00
Position:  X(1): 10063618.00  X(2): 10340829.00  X(3):    -2700.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  7 is    208115.00 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    3.43 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth     .14 degrees.
Probability of Radar Detection is  .516. Random number is  .530.
  Red  7 is not detected.
Red  8  Mission Code 118  Speed  700.00 fps,  Time    745.00
Position:  X(1): 10064094.00  X(2): 10342145.00  X(3):    -2900.00
Velocity:  X(1):    -.3396     X(2):    -.9406     X(3):    .0000
Radar range, Blue 1 to Red  8 is    209091.64 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    3.35 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth     .12 degrees.
Probability of Radar Detection is  .508. Random number is  .343.
  Red  8   is   detected.
Red  9  Mission Code 114  Speed  850.00 fps,  Time    745.00
Position:  X(1): 10041400.00  X(2): 10289145.00  X(3):   -11408.03
Velocity:  X(1):    -.1417     X(2):    -.9899     X(3):    .0000
Radar range, Blue 1 to Red  9 is    175160.80 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    1.45 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   14.00 degrees.
Probability of Radar Detection is  .790. Random number is  .448.
  Red  9   is   detected.
Red 10  Mission Code 114  Speed  850.00 fps,  Time    745.00
Position:  X(1): 10042326.00  X(2): 10290325.00  X(3):   -11408.03
```

```
Velocity:  X(1):    -.1417     X(2):    -.9899     X(3):     .0000
Radar range, Blue 1 to Red 10 is    175507.80 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    1.45 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   13.52 degrees.
Probability of Radar Detection is  .787. Random number is  .185.
  Red 10   is   detected.
Red 11  Mission Code 114  Speed  850.00 fps,  Time    745.00
Position:  X(1): 10057802.00  X(2): 10298248.00  X(3):   -15309.75
Velocity:  X(1):    -.1903     X(2):    -.9817     X(3):     .0000
Radar range, Blue 1 to Red 11 is    172854.09 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is     .20 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    7.86 degrees.
Probability of Radar Detection is  .810. Random number is  .041.
  Red 11   is   detected.
Red 12  Mission Code 114  Speed  850.00 fps,  Time    745.00
Position:  X(1): 10070433.00  X(2): 10301483.00  X(3):   -15717.93
Velocity:  X(1):     .5163     X(2):    -.8561     X(3):    -.0244
Radar range, Blue 1 to Red 12 is    169223.17 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is     .09 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth    3.66 degrees.
Probability of Radar Detection is  .840. Random number is  .111.
  Red 12   is   detected.
Red 41  Mission Code 114  Speed  850.00 fps,  Time    745.00
Position:  X(1):  9924187.00  X(2): 10404725.00  X(3):   -13026.68
Velocity:  X(1):     .1841     X(2):    -.9829     X(3):     .0000
Radar range, Blue 1 to Red 41 is    339068.91 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    -.12 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   17.24 degrees.
Probability of Radar Detection is  .000. Random number is  .197.
  Red 41 is not detected.
Red 42  Mission Code 114  Speed  850.00 fps,  Time    745.00
Position:  X(1):  9924685.00  X(2): 10406140.00  X(3):   -13026.68
Velocity:  X(1):     .1841     X(2):    -.9829     X(3):     .0000
Radar range, Blue 1 to Red 42 is    339790.53 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is    -.13 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   17.02 degrees.
Probability of Radar Detection is  .000. Random number is  .148.
  Red 42 is not detected.
Red 43  Mission Code [illegible]  Sp[illegible]   850.00 fps,  Time    745.00
Position:  X(1):  99230[illegible].00  X(2): 10410570.00  X(3):   -19337.86
Velocity:  X(1):     .1841     X(2):    -.9829     X(3):     .0000
Radar range, Blue 1 to Red 43 is    344096.44 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
```

```
  Target elevation is   -1.19 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   16.72 degrees.
Probability of Radar Detection is  .000. Random number is  .589.
  Red 43 is not detected.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    745.00
Position:  X(1):  9923804.00  X(2): 10411985.00  X(3):   -19337.86
Velocity:  X(1):     .1843     X(2):   -.9829     X(3):     .0000
Radar range, Blue 1 to Red 44 is    344688.97 feet
Radar detection limits are:
  Elevation:  Upper    -5.91 degrees, Lower    6.09 degrees.
  Target elevation is   -1.19 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   16.48 degrees.
Probability of Radar Detection is  .000. Random number is  .502.
  Red 44 is not detected.
Nthrt Blue(1) =   9    Time:     745.00      Flag =   1,  Msn Code =  120
Threat Call Signs are:  12          11          9         10          1
Threat Ranges are:  169223.17  172854.09  175160.80  175507.80  202363.53

Nthrt Blue(1) =  10    Time:     750.00      Flag =   1,  Msn Code =  120
Threat Call Signs are:  12          11          9         10          1
Threat Ranges are:  161732.86  166591.95  169150.28  169463.94  196290.78

Nthrt Blue(1) =   8    Time:     755.00      Flag =   1,  Msn Code =  120
Threat Call Signs are:  12          11          9         10          1
Threat Ranges are:  154117.22  160278.72  163113.44  163390.91  189547.84

Nthrt Blue(1) =  11    Time:     760.00      Flag =   1,  Msn Code =  120
Threat Call Signs are:  12          11          9         10          1
Threat Ranges are:  146376.23  153924.28  157063.48  157301.50  182635.72

Nthrt Blue(1) =  11    Time:     765.00      Flag =   1,  Msn Code =  120
Threat Call Signs are:  12          11          9         10          1
Threat Ranges are:  138509.52  147540.41  151015.97  151210.86  175603.88

Nthrt Blue(1) =  11    Time:     770.00      Flag =   1,  Msn Code =  120
Threat Call Signs are:  12          11          9         10          2
Threat Ranges are:  130517.48  141141.70  144990.94  145138.58  169798.81

Nthrt Blue(1) =  12    Time:     775.00      Flag =   1,  Msn Code =  120
Threat Call Signs are:  12          11          9         10          1
Threat Ranges are:  122400.09  134745.69  139009.92  139105.59  161185.66

Nthrt Blue(1) =  11    Time:     780.00      Flag =   1,  Msn Code =  120
Threat Call Signs are:  12          11          9         10          1
Threat Ranges are:  114157.85  128374.32  133098.53  133136.98  153801.91

Nthrt Blue(1) =  12    Time:     785.00      Flag =   1,  Msn Code =  120
Threat Call Signs are:  12          11         10          9          1
Threat Ranges are:  105790.29  122053.13  127263.70  127288.38  146303.27

Nthrt Blue(1) =  12    Time:     790.0       Flag =   1,  Msn Code =  120
Threat Call Signs are:  12          11         10          9          1
Threat Ranges are:   97297.38  115814.35  121522.81  121617.20  138691.56
```

```
Nthrt Blue(1) =  10    Time:     795.00     Flag =   1,  Msn Code =   120
Threat Call Signs are:  12           11           10           9           3
Threat Ranges are:    88679.63  109698.57  115959.64  116130.99  133623.23
```

Example 7. Radar Detection

As soon as the range is less than 90,000 feet, the radar locks on to the nearest target. The 'Flag' is changed to '2' and information is provided about only the locked-up target as shown below in Example 8.

```
Blue 1,  Mission Code 120,  Speed  910.00 fps,  Time    800.00
Position:  X(1): 10132578.00  X(2): 10191141.00  X(3):   -18724.54
Velocity:  X(1):   -.4360     X(2):     .8997     X(3):     .0223
Nthrt Blue(1) =   1    Time:     800.00     Flag =   2,  Msn Code =  120
Threat Call Signs are:  12          0            0            0           0
Threat Ranges are:    79936.53  999999.00  999999.00  999999.00  999999.00
```

Example 8. Radar Detection

When the fighter is within tactical missile range (see Weapons Employment, this chapter) a missile is launched and the 'Flag' is changed to '3', indicating a radar missile in flight. The radar will stay locked on until the missile reaches the target, (pilot maneuvers permitting) so the missile can track the target.

```
Blue  1 launched radar missile at Red  12, Range   47426.55, Time:    819.00

Blue 1,  Mission Code 120,  Speed 1000.00 fps,  Time    820.00
Position:  X(1): 10124113.00  X(2): 10208407.00  X(3):   -18294.36
Velocity:  X(1):   -.4754     X(2):     .8794     X(3):     .0233
Nthrt Blue(1) =   1    Time:     820.00     Flag =   3,  Msn Code =  120
Threat Call Signs are:  12          0            0            0           0
Threat Ranges are:    43728.84  999999.00  999999.00  999999.00  999999.00

Blue 1,  Mission Code 120,  Speed 1000.00 fps,  Time    825.00
Position:  X(1): 10121748.00  X(2): 10212811.00  X(3):   -18178.05
Velocity:  X(1):   -.4708     X(2):     .8819     X(3):     .0232
Nthrt Blue(1) =   1    Time:     825.00     Flag =   3,  Msn Code =  120
Threat Call Signs are:  12          0            0            0           0
Threat Ranges are:    34482.22  999999.00  999999.00  999999.00  999999.00
```

```
Blue 1,  Mission Code 120,  Speed 1000.00 fps,  Time    830.00
Position:  X(1): 10119413.00  X(2): 10217232.00  X(3):   -18062.53
Velocity:  X(1):    -.4640     X(2):     .8855     X(3):     .0230
Nthrt Blue(1) =   1    Time:     830.00     Flag =   3,  Msn Code =  120
Threat Call Signs are:  12          0          0          0          0
Threat Ranges are:   25236.29  999999.00  999999.00  999999.00  999999.00

Blue 1,  Mission Code 120,  Speed 1000.00 fps,  Time    835.00
Position:  X(1): 10117125.00  X(2): 10221676.00  X(3):   -17948.25
Velocity:  X(1):    -.4525     X(2):     .8915     X(3):     .0227
Nthrt Blue(1) =   1    Time:     835.00     Flag =   3,  Msn Code =  120
Threat Call Signs are:  12          0          0          0          0
Threat Ranges are:   15994.70  999999.00  999999.00  999999.00  999999.00

Red   12 shot down by radar missile,
          coord N 10111699.00, E 10233051.00   Time:       840.00
```

Example 9. Radar Detection

After the missile reaches the target, the radar either goes back to search (if the target was killed) or remains locked on to the target. In this case the radar returned to search, as seen in Example 10 below. All the close targets are beneath the radar search pattern as indicated by the target elevation numbers well in excess of the radar elevation settings. The two detected targets are too far away for any action to be taken, so the fighter is reassigned to a CAP pattern (Mission Code 111).

```
Blue 1,  Mission Code 111,  Speed  995.00 fps,  Time    840.00
Position:  X(1): 10115000.00  X(2): 10226191.00  X(3):   -17840.92
Velocity:  X(1):    -.3599     X(2):     .9328     X(3):     .0177
Red  1  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10078432.00  X(2): 10269149.00  X(3):    -1500.00
Velocity:  X(1):     .2914     X(2):    -.9566     X(3):     .0000
Radar range, Blue 1 to Red  1 is     58733.59 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   15.10 degrees.
Red  2  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10078024.00  X(2): 10270489.00  X(3):    -1700.00
Velocity:  X(1):     .2914     X(2):    -.9566     X(3):     .0000
Radar range, Blue 1 to Red  2 is     59917.16 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
```

```
  Target elevation is   14.58 degrees.
Red  3  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10077616.00  X(2): 10271829.00  X(3):    -1900.00
Velocity:  X(1):     .2914     X(2):    -.9566     X(3):    .0000
Radar range, Blue 1 to Red  3 is     61110.58 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   14.07 degrees.
Red  4  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10077208.00  X(2): 10273169.00  X(3):    -2100.00
Velocity:  X(1):     .2914     X(2):    -.9566     X(3):    .0000
Radar range, Blue 1 to Red  4 is     62313.27 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   13.59 degrees.
Red  5  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10076800.00  X(2): 10274509.00  X(3):    -2300.00
Velocity:  X(1):     .2914     X(2):    -.9566     X(3):    .0000
Radar range, Blue 1 to Red  5 is     63524.71 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   13.12 degrees.
Red  6  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10076392.00  X(2): 10275849.00  X(3):    -2500.00
Velocity:  X(1):     .2914     X(2):    -.9566     X(3):    .0000
Radar range, Blue 1 to Red  6 is     64744.41 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   12.66 degrees.
Red  7  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10075984.00  X(2): 10277189.00  X(3):    -2700.00
Velocity:  X(1):     .2914     X(2):    -.9566     X(3):    .0000
Radar range, Blue 1 to Red  7 is     65971.90 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   12.23 degrees.
Red  8  Mission Code 118  Speed  700.00 fps,  Time    840.00
Position:  X(1): 10075576.00  X(2): 10278529.00  X(3):    -2900.00
Velocity:  X(1):     .2914     X(2):    -.9566     X(3):    .0000
Radar range, Blue 1 to Red  8 is     67206.77 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   11.81 degrees.
Red  9  Mission Code 114  Speed  850.00 fps,  Time    840.00
Position:  X(1): 10029967.00  X(2): 10209250.00  X(3):   -11408.03
Velocity:  X(1):    -.1418     X(2):    -.9899     X(3):    .0000
Radar range, Blue 1 to Red  9 is     86942.45 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.23 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   80.17 degrees.
Red 10  Mission Code 114  Speed  850.00 fps,  Time    840.00
Position:  X(1): 10030893.00  X(2): 10210430.00  X(3):   -11408.03
Velocity:  X(1):    -.1418     X(2):    -.9899     X(3):    .0000
```

```
Radar range, Blue 1 to Red 10 is     85812.46 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is    3.28 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   79.52 degrees.
Red 11  Mission Code 114  Speed  850.00 fps,  Time    840.00
Position:  X(1): 10042412.00  X(2): 10219018.00  X(3):   -15309.75
Velocity:  X(1):    -.1901     X(2):    -.9818     X(3):    .0000
Radar range, Blue 1 to Red 11 is     72985.45 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .97 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   74.55 degrees.
Red 41  Mission Code 114  Speed  850.00 fps,  Time    840.00
Position:  X(1):  9939046.00  X(2): 10325400.00  X(3):   -13026.68
Velocity:  X(1):     .1841     X(2):    -.9829     X(3):    .0000
Radar range, Blue 1 to Red 41 is    202053.00 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .35 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   39.49 degrees.
Probability of Radar Detection is  .566. Random number is  .818.
  Red 41 is not detected.
Red 42  Mission Code 114  Speed  850.00 fps,  Time    840.00
Position:  X(1):  9939544.00  X(2): 10326815.00  X(3):   -13026.68
Velocity:  X(1):     .1841     X(2):    -.9829     X(3):    .0000
Radar range, Blue 1 to Red 42 is    202319.48 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is     .35 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   39.07 degrees.
Probability of Radar Detection is  .564. Random number is  .113.
  Red 42   is   detected.
Red 43  Mission Code 114  Speed  850.00 fps,  Time    840.00
Position:  X(1):  9940253.00  X(2): 10332655.00  X(3):   -19324.88
Velocity:  X(1):     .1768     X(2):    -.9843     X(3):    .0000
Radar range, Blue 1 to Red 43 is    204629.67 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   -1.43 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   37.55 degrees.
Probability of Radar Detection is  .545. Random number is  .316.
  Red 43   is   detected.
Red 44  Mission Code 114  Speed  850.00 fps,  Time    840.00
Position:  X(1):  9956210.00  X(2): 10343010.00  X(3):   -19242.14
Velocity:  X(1):     .7730     X(2):    -.6345     X(3):    .0032
Radar range, Blue 1 to Red 44 is    197136.77 feet
Radar detection limits are:
  Elevation:  Upper    -2.00 degrees, Lower    8.00 degrees.
  Target elevation is   -1.42 degrees.
Azimuth limits are: +/-  55.00 degrees. Target azimuth   32.56 degrees.
Probability of Radar Detection is  .607. Random number is  .927.
  Red 44 is not detected.
Nthrt Blue(1) =   2    Time:    840.00     Flag =   1,  Msn Code =  111
```

Threat Call Signs are: 42 43 0 0 0
Threat Ranges are: 202319.48 204629.67 999999.00 999999.00 999999.00

Example 10. Radar Detection

The above sequence of figures shows how the radar detection subroutine works in all its modes.

Part II: Intercept

Intercept Verification Listing

* The fighter's velocity vector corresponds to the CAP pattern. The airspeed will increase to 1.2 * target airspeed, or 840 fps. The fighter will descend to 9500 ft and stay at that altitude until approximately 8 NM or 48,000' and then will turn to point directly at the target. Note that the fighter's velocity vector does not precisely match the intercept vector (Int vec) because he is maintaining his altitude and the intercept vector is computed for proceeding directly to the intercept point.

```
Blue   1 committed from CAP  1, Time:  751.00
Target Red  1, altitude   1500.00 ft.  Attack will be from above.
     Attack altitude   9500.00 ft.
Blue 1 intercepting Red  1, Range   32.61 NM, Time    751.00
Missile Employment Ranges are:
     Radar Missiles:  Max Range:   44297.73 ft, Min Range:   12227.92
     Heat Missiles:   Max Range:   19466.89 ft Min Range:    4856.22
Intercept Calculations: Ftr Blue 1, Tgt Red  1, Intcpt in  180.17 seconds.
Ftr Speed  585.00 fps, Tgt Speed  700.00 fps.
Ftr pos:  X(1):10157393.00  X(2):10160675.00  X(3):  -20000.04
    Vel:  X(1):    -.1322   X(2):     .9912   X(3):     .0000
Tgt pos:  X(1):10060260.00  X(2):10329490.00  X(3):   -1500.00
    Vel:  X(1):     .0204   X(2):    -.9998   X(3):     .0000
Ftr LOS:  X(1):    -.4965   X(2):     .8629   X(3):     .0946
Int vec:  X(1):    -.8971   X(2):     .4054   X(3):     .1755


Target Red  1, altitude   1500.00 ft.  Attack will be from above.
     Attack altitude   9500.00 ft.
Blue 1 intercepting Red  1, Range   21.08 NM, Time    803.00
Missile Employment Ranges are:
     Radar Missiles:  Max Range:   46592.45 ft, Min Range:   12883.56
     Heat Missiles:   Max Range:   20450.34 ft Min Range:    5129.40
Intercept Calculations: Ftr Blue 1, Tgt Red  1, Intcpt in   84.12 seconds.
Ftr Speed  840.00 fps, Tgt Speed  700.00 fps.
Ftr pos:  X(1):10133970.00  X(2):10185384.00  X(3):   -9653.52
    Vel:  X(1):    -.6573   X(2):     .7537   X(3):     .0000
Tgt pos:  X(1):10070680.00  X(2):10294609.00  X(3):   -1500.00
    Vel:  X(1):     .2914   X(2):    -.9566   X(3):     .0000
Ftr LOS:  X(1):    -.5003   X(2):     .8634   X(3):     .0645
Int vec:  X(1):    -.6529   X(2):     .7486   X(3):     .1154


Blue 1 locking on to Red  1, Range   14.57 NM, Time    829.00
Target Red  1, altitude   1500.00 ft.  Attack will be from above.
     Attack altitude   9500.00 ft.
Blue 1 intercepting Red  1, Range   14.57 NM, Time    829.00
Missile Employment Ranges are:
```

```
     Radar Missiles:  Max Range:   46521.39 ft, Min Range:   12863.26
     Heat Missiles:   Max Range:   20419.88 ft Min Range:    5120.94
Intercept Calculations: Ftr Blue 1, Tgt Red  1, Intcpt in   58.26 seconds.
Ftr Speed  840.00 fps, Tgt Speed  700.00 fps.
Ftr pos:  X(1):10119612.00  X(2):10201842.00  X(3):   -9653.52
    Vel:  X(1):    -.6579   X(2):     .7531   X(3):     .0000
Tgt pos:  X(1):10075984.00  X(2):10277189.00  X(3):   -1500.00
    Vel:  X(1):     .2914   X(2):    -.9566   X(3):     .0000
Ftr LOS:  X(1):    -.4989   X(2):     .8616   X(3):     .0932
Int vec:  X(1):    -.6487   X(2):     .7426   X(3):     .1666


Target Red  1, altitude   1500.00 ft.  Attack will be from above.
     Attack altitude   9500.00 ft.
Blue 1 intercepting Red  1, Range    7.60 NM, Time    857.00
Missile Employment Ranges are:
     Radar Missiles:  Max Range:   46214.05 ft, Min Range:   12775.44
     Heat Missiles:   Max Range:   20288.16 ft Min Range:    5084.35
Target within radar range, must be within 40 degrees of nose.
     Tgt bears  13.6 degrees off nose.


Blue  1 launched radar missile at Red  1, Range  45621.90, Time:  857.00
Intercept Calculations: Ftr Blue 1, Tgt Red  1, Intcpt in   29.65 seconds.
Ftr Speed  840.00 fps, Tgt Speed  700.00 fps.
Ftr pos:  X(1):10103613.00  X(2):10220103.00  X(3):   -9138.37
    Vel:  X(1):    -.6288   X(2):     .7145   X(3):     .3066
Tgt pos:  X(1):10081900.00  X(2):10257759.00  X(3):   -1500.00
    Vel:  X(1):     .2914   X(2):    -.9566   X(3):     .0000
Ftr LOS:  X(1):    -.4920   X(2):     .8532   X(3):     .1731
Int vec:  X(1):    -.6288   X(2):     .7145   X(3):     .3066
```

Appendix C

Program Listing

```
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      equivalence (nset(1),qset(1))
      dimension  nset(15000)
*
*  The program will run with NSET/QSET dimensioned to
*    10,000. but multiple runs require 15,000.
*
      common  qset(15000)
      ncrdr=5
      nprnt=6
      ntape=7
      nnset=15000
      call slam
      stop
      end
*
**************************Subroutine Intlc****************************
*
      subroutine intlc
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstip,nclnr,
     + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  a(10),b(10)
      data  thrt/ 264*999999/vthrt/24*555555/nsectr/6*0/ncap/3*0/
     1  ithrt/264*0/nthrt/24*0/ivthrt/24*0/
     2  itrr,ivtrr,thtrr,vtrr/1920*0/ntrr/80*0/
      ssl(1)=1
      ssl(2)=1
*
*  The 'db' array is used to turn write
*    statements on and off.
*
*
*  When 'db(1)' is .true. the contents of all the
*     files are printed before exiting from Intlc.
*
      data  a,b/20*0/db/20*.false./
      db(5) = .true.
```

```
      nb=24
      nr=80
*
*  'nb' and 'nr' are the number of Blue and the
*    number of Red aircraft available.
*
      do 32 j1 = 1,14
        xx(j1) = 0
   32 continue
      xx(1) = 4
      xx(2) = 16
*
*  XX(1) and XX(2) are the number of
*    Blue and Red aircraft involved
*    in the simulation run.
*
      blue(1) = 10e6
      blue(2) = 10e6
      blue(3) = 0
*
*  'blue' is an array which holds the coordinates
*      of the blue airrfield.
*
      a(1)=10e6
      a(2)=10e6
      do  12  j1 = 1,nb
        call filem(1,a)
 12   continue
*
*  The aero information and operational files
*     are initiallized with the values the
*     aircraft would have sitting on the base.
*
      a(1)=0
* The first element will be the wingman's call sign.
      a(2)=14500
*  Second:  fuel load in pounds.
      a(3)=4
*  Third:  number of radar missiles.
      a(4)=4
*  Fourth:  number of heatseeking (IR) missiles.
      a(5)=9
*  Fifth:  number of seconds of cannon fire.
      a(9)=4
*  Ninth:  mission flag (4 denotes departing base).
      a(10)=110
*  Tenth:  mission code (110 is available for flight).
      do  14  i1=1,nb
        call filem(2,a)
 14   continue
      do  10  i1=1,nb
        call filem(3,b)
 10   continue
*
```

```
*  File 3 is initialized to zero.
*
*  File 3 will hold information on radar missiles
*     fired by blue aircraft.
*
      do  16  i2=1,nr
        call filem(8.b)
 16   continue
*
*  File 8 will hold information on radar
*     missiles fired by red aircraft.
*
      redb(1,1) = 10.12e6
      redb(1,2) = 10.84e6
      redb(1,3) = 0
*
*  The 'redb' array holds the coordinates
*     of the red airbases.
*
      b(1)=10.12e6
      b(2)=10.84e6
      do  18  i2=1,40
         call filem(6,b)
 18   continue
*
*  File 6 has aero information and File 7
*     has operational information for
*     'red' aircraft.
*
      redb(2,1) = 9.82e6
      redb(2,2) = 10.96e6
      redb(2,3) = 0
      b(1)=9.82e6
      b(2)=10.96e6
      do  20  j1=1,40
        call filem(6,b)
 20   continue
      redb(3,1) = 9.784e6
      redb(3,2) = 10.108e6
      redb(3,3) = 0
      b(1)=0
      b(2)=8000
      b(3)=2
      b(4)=2
      b(5)=6
      b(9)=4
*
*  The information in Files 6 & 7 is
*    completely analogous to that in Files 1 & 2.
*
      b(10)=110
      do  24  j1=1,nr
        call filem(7,b)
 24   continue
```

```
         a(1)= 10154269
         a(2)=10183851
         a(3)=-20000
*
*  Coordinates for CAP 1 (X1, X2, X3).
*
         a(4)=cos(275./57.3)
         a(5)=sin(275./57.3)
         a(6)=0
*
*  Vector for outbound CAP 1 heading.
*
         a(7)=0
         a(8)=0
         a(9)=0
         a(10)=2
         call filem(5,a)
         a(1)=9981697
         a(2)=10209201
         a(4)=cos(270./57.3)
         a(5)=sin(270./57.3)
*
*  CAP 2 information.
*
         a(10)=0
*
*  File 5 has coordinates and patterns for
*     'blue' Combat Air Patrols (CAPs)
*
         call filem(5,a)
         a(1)=9.91e6
         a(2)=10115885
         a(4)=cos(260./57.3)
         a(5)=sin(260./57.3)
*
*  CAP 3 information.
         call filem(5,a)
         a(1) = 10.09e6
         a(2) = 10.42e6
         a(3) = 9.916e6
         a(4) = 10.42e6
         call filem(10,a)
*
*  File 10 has route of flight waypoints for
*     'red' aircraft.
*    The above four numbers are the first waypoints
*      for Routes 1 & 2 (X1, X2 coordinates).
*    The numbers are filed in First In, First Out
*      (FIFO) order, so the first ones in are
*      positioned in the first entity of the file.
*
         a(1) = 10.06e6
         a(2) = 10.33e6
         a(3) = 9.88e6
```

```
      a(4) = 10.324e6
      call filem(10,a)
      a(1) = 10.12e6
      a(2) = 10.14e6
      a(3) = 9.928e6
      a(4) = 10.14e6
      call filem(10,a)
      a(1) = 9.976e6
      a(2) = 10.072e6
      a(3) = 10.06e6
      a(4) = 10.33e6
      call filem(10,a)
      a(1) = 10e6
      a(2) = 10.24e6
      a(3) = 10.09e6
      a(4) = 10.42e6
      call filem(10,a)
      a(1) = 10.06e6
      a(2) = 10.408e6
      a(3) = 9.82e6
      a(4) = 10.96e6
      call filem(10,a)
      a(1) = 10.12e6
      a(2) = 10.84e6
      a(3) = 999
      a(4) = 999
      call filem(10,a)
      a(1) = 999
      a(2) = 999
      call filem(10,a)
      atrib(1) = 1
      atrib(2) = 2
      atrib(3) = 1
      atrib(4) = 2
*     call schdl(1,500.,atrib)
*     atrib(1) = 2
*     call schdl(1,500.,atrib)
*
*  An aircraft is initially scheduled into
*     each of the 'Blue' CAPs (Event 1).
*  Note:  calls to 'schdl' MUST have a real
*    number in the time slot or the event
*    will occur at Time 0.
*
*     atrib(1) = 3
*     call schdl(1,1.,atrib)
      atrib(1) = 1
      atrib(2) = 1
      atrib(3) = 1
      atrib(4) = 8
      do  26  j1 = 1,8
        d1 = j1*2+10
        call schdl(9,d1,atrib)
        atrib(2) = atrib(2)+1
```

```
   26 continue
*        atrib(1) = 2
*        atrib(2) = 1
*        atrib(3) = 2
*        do  28  j1 = 1,8
*          d1 = j1*2+410
*          call schdl(9,d1,atrib)
*          atrib(2) = atrib(2)+1
*   28 continue
*
*   Two 'red' raids are scheduled to
*      complete the scenario (Event 9).
*
        atrib(1) = 1
        atrib(2) = 1
        atrib(3) = 1
*       call schdl(8,97.,atrib)
*       call schdl(8,120.,atrib)
        atrib(2) = 2
*       call schdl(8.90.,atrib)
*       call schdl(8,127.,atrib)
*
*   Event 8 schedules Red escort fighters.
*
        atrib(1) = 2
        atrib(2) = 1
        atrib(3) = 41
*       call schdl(8,67.,atrib)
*       call schdl(8,115.,atrib)
        atrib(2) = 2
*       call schdl(8,60.,atrib)
*       call schdl(8,122.,atrib)
*       call schdl(10,5.,atrib)
*
*   Event 10 is Radar detection.  This starts
*     it up.
*
        if (db(1)) then
          do  30  j1 = 1,11
            call prntf(j1)
   30     continue
        endif
*
*   If db(1) is set, all files are printed
*     out after initialization.
*
        return
        end
*
***************************Subroutine State*******************************
*
        subroutine state
        common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
       + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
```

```
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      logical  thru,red
      character*4  cs
      ss(1) = ssl(1)*dtnow
      ss(2) = ssl(2)+dtnow
*
*  These are dummy equations to get the continuous
*    time advance mechanism to function properly.
*
      if  ((dtnow.eq.0).and.(tnow.gt.0)) return
*     do  52  j1 = 1,6
*       nsectr(j1) = 0
*  52 continue
*
*  The 'Blue' radar missile file is checked for
*     missiles in flight and they are updated.
*
        ntry3 = mmfe(3)
        do  30  j1 = 1,nb
          if (qset(ntry3+1).gt.0) call cmp70(j1,7,1,3)
          ntry3 = nsucr(ntry3)
  30    continue
*
*  The 'Red' radar missile file is checked in
*    like manner.
*
        ntry8 = mmfe(8)
        do  32  j1 = 1,nr
          if (qset(ntry8+1).gt.0) call cmp70(j1,7,1,8)
          ntry8 = nsucr(ntry8)
  32    continue
*
*  The Infrared (IR) files is also searched for
*     heat-seeking missiles in flight and they
*     are updated.
*
        if (nnq(4).gt.0) call cmp60(4,6,1,1)
        if (nnq(9).gt.0) call cmp60(9,6,1,1)
*
*  Now a sweep is made through the blue
*    and red aircraft files and the aero
*    information (position and velocity)
*    is updated.
*
      n1 = nb
      n4 = 0
      thru =.false.
      red = .false.
```

```
      cs = 'Blue'
      bingo = 4500
      accel = 5
*
*  These index and pointer variables are
*    set for blue aircraft and will be
*    reset for red aircraft at the
*    bottom of the loop.
*
      ntry1 = mmfe(1)
      rtry2 = mmfe(2)
   10 continue
      do  20  j1 = 1,n1
        if (qset(ntry2+10).gt.110) then
*
*  The mission code is checked to see if
*    aircraft is airborne.
*
          n2 = qset(ntry2+10)-110
          n3 = qset(ntry2+1)
*         if (tnow.gt.1000)
*    +      write(8,'(5x,a5,2x,i2,', Msn Code ',i2,', Wgmn ',i2,
*    +        ', Flag =',f3.0,', Time ',f9.2)')cs,j1,n2,n3,
*    +        qset(ntry2+9),tnow
          go to (100,100,100,400,101,101,101,800,900,1000,1100),n2
101         write(8,'(5x,'Incorrect code for subroutine call in
     +        'Subroutine State, Code was ',i3,', Time ',f9.2)')n2,tnow
            stop
100         call cmp10(j1,n2,n3,n4)
            go to 8
400         call cmp40(j1,n2,n3,n4)
            go to 8
800         call cmp80(j1,n2,n3,n4)
            go to 8
900         call cmp90(j1,n2,n3,n4)
            go to 8
1000        call cmp100(j1,n2,n3,n4)
            go to 8
1100        call cmp110(j1,n2,n3,n4)
    8     continue
*
*
*  Subroutine 'cmpute' manipulates the
*    aircraft velocity vector and performs
*    various operational chores and returns
*    the aircraft to 'state' for updating
*    of position and fuel.
*
          delta = qset(ntry1+9) - qset(ntry1+7)
          if (abs(delta).le.5) then
            qset(ntry1+7) = qset(ntry1+9)
          else
            if (delta.gt.0) qset(ntry1+7) = qset(ntry1+7) + accel
            if (delta.lt.0) qset(ntry1+7) = qset(ntry1+7) - accel
```

```
          endif
          vel = qset(ntry1+7)
          do  12  j2 = 1,3
            qset(ntry1+j2) = qset(ntry1+j2)+qset(ntry1+3+j2)*dtnow*vel
   12     continue
          n5 = qset(ntry2+9)
          n6 = qset(ntry2+10)
          if ((db(4)).and.(j1.le.4))
     +    write(8,'(5x,'Call Sign ',a4,2x,i3,', Mission Code ',i3,
     +      ', Time:  ',f8.2,', Flag = ',i3,', Vel ',f8.2/
     +      5x,'Updating position, ',3('X',i1,' = ',f12.2,3x))')
     +      cs,j1,n6,tnow,n5,vel,1,qset(ntry1+1),2,
     +      qset(ntry1+2),3,qset(ntry1+3)
          if((db(4)).and.(j1.le.4))
     +    write(8,'(5x,'Updating velocity, ',3('X',i1,' = ',f12.2,3x))')
     +      1,qset(ntry1+4),2,qset(ntry1+5),3,qset(ntry1+6)
*
*  Update Fuel
          qset(ntry1+8) = (10000-20000*min(0.,qset(ntry1+6)))/3600.
          if (red) qset(ntry1+8) = 0.6*qset(ntry1+8)
          qset(ntry2+2) = qset(ntry2+2)-qset(ntry1+8)*dtnow
          if ((qset(ntry2+2).lt.bingo).and.(abs(qset(ntry2+9)).le.1))
     +      then
            if (qset(ntry2+10).ne.119) then
              qset(ntry2+10) = 119
              if (db(5))
     +        write(8,'(5x,'Aircraft ',i3,' went bingo at ',f8.2)')j1,
     +          tnow
            endif
          endif
*
*  Update Sectors with the number of red
*    aircraft in each sector.
*
*         if (red) then
*           nsec = 5
*           if (qset(ntry1+2).lt.10.45e6) nsec = 1
*           if (qset(ntry1+2).lt.10.38e6) nsec = 3
*           if (qset(ntry1+1).lt.10e6) nsec = nsec+1
*           nsectr(nsec) = nsectr(nsec)+1
*         endif
*
        endif
*
*  The file pointers are incremented to
*    the next aircraft.
*
        ntry1 = nsucr(ntry1)
        ntry2 = nsucr(ntry2)
   20 continue
      if (thru) return
*
*  The index and pointer variables are set
*     for the red aircraft files.
```

```
*
      accel = 7
      bingo = 2500
      n1 = nr
      n4 = 5
      red = .true.
      thru = .true.
      cs = ' Red'
      ntry1 = mmfe(6)
      ntry2 = mmfe(7)
      go to 10
      end
*
**************************Subroutine Event*******************************
*
      subroutine event(iev)
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  nsgn(20),iwg(20),vb1(3),vr1(3),
     + xlos(3),threat(24),red(80),ired(80)
      data red,ired/80*999999,80*0/threat/24*999999/nsgn,iwg/40*0/
*     write(8,'(5x,'Enter Event, E Code ',i3,', Time: ',f9.2)')iev,tnow
      go to (1000,1001,1001,1001,1001,1001,1001,8000,9000,
     +  10000                                        ),iev
 1001 write(8,'(5x,'Incorrect Event code',i8)')iev
      stop
************************************************************************
*  CAP ASSIGNMENT SECTION:  Forms flights of aircraft and              *
*                           assigns them to CAP 1/2/3 as requested     *
************************************************************************
 1000 n1=atrib(3)
      n2=atrib(2)
      i2 = atrib(4)
      n3 = atrib(1)
      j4 = nb
*
*  The necessary information is passed through
*     the atributes.
*         Atrib(1):  CAP #
*         Atrib(2):  # of aircraft in flt
*         Atrib(3):  # of flts
*         Atrib(4):  file pointer
*
      do  1016 j1=1,n1
*
*  A sweep is made through the aircraft files
*    and aircraft which are available (as
```

```
*    denoted by the 110 mission code) are
*    formed into flights of the requested
*    size.
*
         ntry2=mmfe(2)
         do  1010  j2=1,j4
             if(qset(ntry2+10).eq.110)then
             ntry1 = locat(j2,1)
             ntry2 = locat(j2,2)
             ntry5 = locat(n3,5)
           do  1014  j5 = 1,n2
             do 1018 j6 = 1,3
               qset(ntry1+j6) = qset(ntry5+j6)
               qset(ntry1+3+j6) = -qset(ntry5+3+j6)+.1
 1018        continue
             qset(ntry1+6) = 0
             qset(ntry1+3) = -19987
             qset(ntry1+7) = 585
             qset(ntry1+9) = 585
             qset(ntry1+10) = qset(ntry5+3)
             qset(ntry2+1) = j2+1
             if (j5.eq.2) qset(ntry2+1) = j2
             qset(ntry2+2) = 12500
             qset(ntry2+6) = j5
             qset(ntry2+9) = -1
             qset(ntry2+10) = 110 + atrib(1)
             ntry1 = nsucr(ntry1)
             ntry2 = nsucr(ntry2)
 1014        continue
             ncap(n3) = ncap(n3)+2
             if (db(5))
     +       write (8,'(5x,'Flight ',i3,' of ',i3,' formed at ',f12.2,
     +         ', Mission Code ',i4)')j2,n2,tnow,int(atrib(1)+110)
             return
             endif
             ntry2=nsucr(ntry2)
 1010      continue
*
*  If the required number of aircraft were
*    available they are formed into a
*    flight.
*
 1016 continue
      return
***********************************************************************
*                                                                     *
*                 Red Escort Fighter Scheduling                       *
*                                                                     *
***********************************************************************
 8000 n1 = atrib(1)
      n2 = atrib(2)
      n3 = atrib(3)
      ntry6 = locat(n3,6)
      ntry7 = locat(n3,7)
```

```
      comp = unfrm(0.,1.,9)
      alt = -10000 - comp * 10000
      do  8008  j1 = 1,3
        vr1(j1) = redb(n1,j1)
 8008 continue
      call los(vr1,blue,xlos,xmag,phi)
      x1 = 0
      x2 = 0
      phi = -150./57.3
      do  8010  j1 = n3,n3+39
        if (qset(ntry7+10).eq.110) then
          do  8012  j2 = 1,2
              qset(ntry6+1) = vr1(1) + x1
              qset(ntry6+2) = vr1(2) + x2
              qset(ntry6+3) = alt
              qset(ntry6+4) = xlos(1)
              qset(ntry6+5) = xlos(2)
              qset(ntry6+6) = 0
              qset(ntry6+7) = 850
              qset(ntry6+8) = 1
              qset(ntry6+9) = 850
              qset(ntry6+10) = alt
              qset(ntry7+1) = j1 + j2
              if (j2.eq.2) qset(ntry7+1) = 0
              qset(ntry7+6) = j2
              qset(ntry7+7) = 1
              qset(ntry7+8) = n2
              qset(ntry7+9) = 1
              qset(ntry7+10) = 114
              x1 = 1500 * (xlos(1) * cos(phi) + xlos(2) * sin(phi))
              x2 = 1500 * (xlos(1) * (-sin(phi)) + xlos(2) * cos(phi))
              ntry6 = nsucr(ntry6)
              ntry7 = nsucr(ntry7)
 8012     continue
          write(8,'(5x,'Red Escort ',i3,', flight formed at ',
     +      ' Time ',f9.2)')j1,tnow
          return
        endif
        ntry6 = nsucr(ntry6)
        ntry7 = nsucr(ntry7)
 8010   continue
        return
************************Red Ground Attack******************************
*   Red aircraft are configured and sent out                          *
*     on the proper route as they are scheduled                       *
*     by other routines.                                              *
*     Again, information is passed through                            *
*     the 'atrib' array.                                              *
***********************************************************************
*     Atrib(1):  Base  (1/2/3)
*     Atrib(2):  Callsign
*     Atrib(3):  Route #  (1/2/3)
*     Atrib(4):  # in flight
*
```

```
 9000 n1 = 0
      if (atrib(1).eq.2) n1 = 40
      n2 = atrib(2)
      n3 = atrib(3)
      if (n3.eq.3) n3 = 5
      if (n3.eq.2) n3 = 3
      n4 = atrib(4)
      ntry6 = locat(n1+n2,6)
      ntry7 = locat(n1+n2,7)
      ntry10 =  mmfe(10)
      qset(ntry7+10) = 118
      qset(ntry7+9) = 1
      qset(ntry7+8) = n3
      qset(ntry7+7) = 0
      qset(ntry7+6) = n4*1000+n1+n2
      qset(ntry7+1) = n1+n2+1
      if (n2.eq.1) qset(ntry7+1) = 1
*
*  The aircraft starts at an altitude over
*    the base.
*
      qset(ntry6+10) =  -1300-n2*200
      qset(ntry6+9) = 700
      qset(ntry6+8) = 5000
      qset(ntry6+7) = 700
      qset(ntry6+3) = -1300-n2*200
      vr1(1) = qset(ntry6+1)
      vr1(2) = qset(ntry6+2)
      vr1(3) = 0
      vb1(1) = qset(ntry10+n3)
      vb1(2) = qset(ntry10+n3+1)
      vb1(3) = 0
      call los(vr1,vb1,xlos,xmag,phi)
      qset(ntry6+4) = xlos(1)
      qset(ntry6+5) = xlos(2)
      if (db(5))
     +write(8,'(5x,'Red ',i3,' departed Base ',i2,' on Route ',i2,
     +  '  Time:  ',f8.2)')n1+n2,int(atrib(1)),int(atrib(3)),tnow
      return
10000 call search
      return
      end
*
*   These subroutines support the basic program.
*
      include 'search'
      include 'cmp10'
      include 'cmp40'
      include 'cmp60'
      include 'cmp70'
      include 'cmp80'
      include 'cmp90'
      include 'cmp100'
      include 'cmp110'
```

```
      subroutine turn(vec1,vec2,g,ntry1,dtnow,vel)
*
*  Turns vec1 toward vec2 in the plane vec1-vec2 with 'g' G forces
*
      common  qset(15000)
      common/ucom2/db(20)
      logical  db(20)
      dimension  vec1(3),vec2(3),vec(3),uvec(3)
      call cross(vec1,vec2,vec,uvec)
      call cross(uvec,vee1,vec,uvec)
*     if (db(8))
*    +write(8,'(5x,'Turn, ',3('VEC1(',i1,') = ',f13.5,2x)/
*    +  11x,3('UVEC(',i1,') = ',f13.5,2x)/12x,'Vel = ',f8.2,
*    +  2x,'G = ',f6.2,2x,'DTNOW = ',f8.2,', NTRY = ',i5)')
*    +  (j1,vec1(j1),j1=1,3),(j1,uvec(j1),j1=1,3),vel,g,dtnow,ntry1

      do  10  j1 = 1,3
        vec1(j1) = vec1(j1) * vel
        uvec(j1) = uvec(j1) * g * 32.2 * dtnow
        vec(j1) = vec1(j1) + uvec(j1)
   10 continue
      call unit(vec,uvec)
      do  12  j1 = 1,3
        qset(ntry1+3+j1) = uvec(j1)
   12 continue
*     if (db(9))
*    +  write(8,'(5x,'Turn, Vel Vector:  ',3('V(',i1') = ',f8.4,2x)/
*    +  12x,'OldVector: ',3('V(',i1,') = ',f8.4,2x)/)')(j1,uvec(j1),
*    +  j1=1,3),(j1,vec1(j1),j1=1,3)
      return
      end
      real function hdg(ics)
*
*  Returns the heading of red aircraft callsign 'ics'
*
      common  qset(15000)
      dimension  vec1(3),vec2(3)
      ntry6 = locat(ics,6)
      vec1(1) = qset(ntry6+4)
      vec1(2) = qset(ntry6+5)
      vec1(3) = 0
      vec2(1) = 1
      vec2(2) = 0
      vec2(3) = 0
      call dot(vec2,vec1,dprod,c,theta)
      hdg = theta
      if (vec1(2).lt.0) hdg = 2*acos(-1.0)+theta
      return
      end
      subroutine dot(vec1,vec2,dprod,c,theta)
*
*  Performs scalar multiplication of two vectors.
*
      dimension  vec1(3),vec2(3)
```

```
      xmag1 = sqrt(vec1(1)*vec1(1)+vec1(2)*vec1(2)+vec1(3)*vec1(3))
      xmag2 = sqrt(vec2(1)*vec2(1)+vec2(2)*vec2(2)+vec2(3)*vec2(3))
      dprod = vec1(1)*vec2(1)+vec1(2)*vec2(2)+vec1(3)*vec2(3)
      if ((xmag1.gt.0).and.(xmag2.gt.0)) then
        c = dprod/xmag1/xmag2
        if (c.gt.1) c=1
        if (c.lt.-1) c=-1
      else
        c = 1
      endif
      theta = acos(c)
        return
      end
      subroutine cross(vec1,vec2,vec,uvec)
*
*   Performs vector multiplication of two vectors.
*
      dimension  vec1(3),vec2(3),vec(3),uvec(3)
      vec(1) = vec1(2)*vec2(3)-vec1(3)*vec2(2)
      vec(2) = vec1(3)*vec2(1)-vec1(1)*vec2(3)
      vec(3) = vec1(1)*vec2(2)-vec1(2)*vec2(1)
      xmag = vec(1)*vec(1)+vec(2)*vec(2)+vec(3)*vec(3)
      if (xmag.gt.0) then
        xmag = sqrt(xmag)
        do  10  j1 = 1,3
          uvec(j1) = vec(j1)/xmag
   10   continue
      else
        xmag = 0
        do  12  j1 = 1,3
          uvec(j1) = 0
   12   continue
      endif
      return
      end
      subroutine unit(vec,uvec)
      common/ucom2/db(20)
      logical  db(20)
*
*   Returns a unit vector.
*
      dimension  vec(3),uvec(3)
*     if (db(3))
*    +write(8,'(5x,'Inside UNIT')')
      xmag = 0
      do  10  j1 = 1,3
        xmag = xmag+vec(j1)*vec(j1)
   10 continue
      if (xmag.gt.0) then
        xmag = sqrt(xmag)
        do  12  j1 = 1,3
          uvec(j1) = vec(j1)/xmag
   12   continue
      else
```

```
        do  14  j1 = 1,3
          uvec(j1) = 0
   14   continue
      endif
      return
      end
      subroutine los(vec1,vec2,xlos,xmag,phi)
*
*  Returns line of sight and distance between two points.
*
      dimension  vec1(3),vec2(3),xlos(3)
      xmag = 0
      do  10  j1 = 1,3
        xlos(j1) = vec2(j1)-vec1(j1)
        xmag = xmag+xlos(j1)*xlos(j1)
   10 continue
      if (xmag.gt.0) then
        xmag = sqrt(xmag)
        do  12  j1 = 1,3
          xlos(j1) = xlos(j1)/xmag
   12   continue
      else
        xmag = 0
        do  14  j1 = 1,3
          xlos(j1) = 0
   14   continue
      endif
      phi = asin(xlos(3))
      return
      end
      subroutine otput
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      write(9,'(14(i2,i3))')(int(xx(j1)),j1=1,14)
      return
      end
```

```
      subroutine search
      common/scom1/atrib(100),dd(100).ddl(100),dtnow,ii,mfa,mstop,nclnr,
     + ncrdr,nprnt,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20),redd
      character cs1*4,cs2*4,cs3*5,cs4*6
      real  lowel
      dimension  nsgn(20),iwg(20),vb1(3),vb2(3),vb3(3),vr1(3),vr2(3),
     + vr3(3),xlos(3),threat(24),red(80),ired(80),hlos(3),
     + red1(80),ired1(80)
      data red,ired/80*999999,80*0/threat/24*999999/nsgn,iwg/40*0/
************************************************************************
*                                                                      *
*  RADAR SEARCH SECTION:  Called every 5 seconds                       *
*                                                                      *
************************************************************************
      if (db(11)) write(8,'(5x,'Search, Time ',f9.2)')tnow
      ntry1=mmfe(1)
      ntry2=mmfe(2)
      ntry6 = mmfe(6)
      ntry7 = mmfe(7)
*
*  The angular limits of the radar are
*    set based on what the aircraft is doing
*    at the moment, as shown by his mission
*    code.
*
      lowel = 8./57.3
      upel = -2./57.3
      azlmt = 55./57.3
      trng = 30000
      cs1 = 'Blue'
      cs2 = ' Red'
      redd = .false.
      n4 = nr
      n3 = nb
      n16 = 6
      n17 = 7
10008 continue
      do  10036  n1 = 1,n3
      db(1) = .false.
*     if((.not.(redd)).and.(n1.eq.1))db(1) = .true.
        nred = 0
        nred1 = 0
        if (qset(ntry2+10).lt.111) go to 10034
        if (qset(ntry2+10).eq.121) go to 10034
        do  10010  j1=1,80
          red(j1) = 999999
          red1(j1) = 999999
```

```
          ired(j1) = 0
          ired1(j1) = 0
10010   continue
        do  10012  j1 = 1,3
*
*  The scratch arrays are loaded with position
*    and velocity vectors.
*
          vb1(j1)=qset(ntry1+j1)
          vb2(j1)=qset(ntry1+3+j1)
          vb3(j1)=vb2(j1)
10012   continue
        vb3(3)=0
        call unit(vb3,vb3)
        if (cb(1))
     +    write(8,'(5x,'Blue 1,  Mission Code ',i3,',  Speed ',f7.2,
     +    ' fps,  Time ',f9.2/ 5x,'Position:  ',(3('X(',i1,'):',
     +    f12.2,2x))/5x,'Velocity:  ',3('X(',i1,'):',f9.4,5x))')
     +    int(qset(ntry2+10)),qset(ntry1+7),tnow,
     +    (j2,vb1(j2),j2=1,3),(j2,vb2(j2),j2=1,3)
*
*  A mission code of 120 signifies
*    a radar attack by the aircraft.
*
        if (qset(ntry2+9).lt.1) go to 10018
        if (qset(ntry2+10).eq.120) then
          if (qset(ntry2+9).eq.1) then
            if (ithrt(n1,11).le.0) then
              qset(ntry2+9) = 0
              go to 10018
            endif
            n6 = locat(ithrt(n1,11),n16)
            do  10014  j1 = 1,3
              vr1(j1) = qset(n6+j1)
10014       continue
*
*  If the aircraft is running an intercept on
*    another aircraft but is not locked on,
*    the radar beam is oriented along the line
*    of sight.
*
            call los(vb1,vr1,xlos,xmag,phi)
            phi = asin(xlos(3) - vb2(3))
*
*  Phi is the elevation angle between the LOS
*    vector and the velocity vector or 'nose'
*    of the aircraft.
*
            lowel = phi+6./57.3
            upel = phi-6./57.3
            if (abs(phi).gt.azlmt) then
              lowel = azlmt
              upel = azlmt - 16./57.3
            endif
```

```
            endif
*
*  A value greater than 1.5 implies the radar
*    is locked on or a missile is in flight.
*
            if (qset(ntry2+9).gt.1.5) then
              n6 = ithrt(n1,11)
              if (n6.le.0) then
                if (redd) then
                  itrr(n1,1) = 0
                  itrr(n1,11) = 0
                  thtrr(n1,1) = 999999
                  thtrr(n1,11) = 999999
                  qset(ntry2+9) = 1
                else
                  ithrt(n1,1) = 0
                  ithrt(n1,11) = 0
                  thrt(n1,1) = 999999
                  thrt(n1,11) = 999999
                  qset(ntry2+9) = 0
                endif
                go to 10018
              else
                n6 = locat(n6,n16)
              endif
              do  10016  j1 = 1,3
                vr1(j1) = qset(n6+j1)
                vr2(j1) = qset(n6+3+j1)
                vr3(j1) = vr2(j1)
10016         continue
              vr3(3) = 0
              call unit(vr3,vr3)
              call los(vb1,vr1,xlos,xmag,phi)
              phi = asin(xlos(3) - vb2(3))
              xlos(3) = 0
              call unit(xlos,xlos)
              call dot(vb3,xlos,dprod,c,theta)
              if ((abs(phi).gt.azlmt).or.(abs(theta).gt.azlmt)) then
                if (redd) then
                  itrr(n1,1) = 0
                  itrr(n1,11) = 0
                  thtrr(n1,1) = 999999
                  thtrr(n1,11) = 999999
                  qset(ntry2+9) = 1
                else
                  ithrt(n1,1) = 0
                  ithrt(n1,11) = 0
                  thrt(n1,1) = 999999
                  thrt(n1,11) = 999999
                  qset(ntry2+9) = 0
                endif
                go to 10018
              endif
              thrt(n1,1) = xmag
```

```
                  thrt(n1,11) = xmag
                  nthrt(n1) = 1
                  go to 10032
                endif
              endif
*
*  Each aircraft is checked against other
*    airborne aircraft to build a radar
*    file, much as the pilot's radar
*    scope might do.
*
10018         continue
              ntry6 = mmfe(6)
              ntry7 = mmfe(7)
              if (redd) then
                ntry6 = mmfe(1)
                ntry7 = mmfe(2)
              endif
              do  10026  n2 = 1,n4
                if (qset(ntry7+10).gt.110) then
                  ics = n2
                  do  10020  j1 = 1,3
                    vr1(j1)=qset(ntry6+j1)
                    vr2(j1)=qset(ntry6+3+j1)
                    vr3(j1)=vr2(j1)
10020             continue
                  vr3(3)=0
                  call unit(vr3,vr3)
*           if (db(1))
*     +       write(8,'(5x,'Red ',i2,'  Mission Code ',i3,'  Speed ',f7.2,
*     +       ' fps,  Time ',f9.2/ 5x,'Position:  ',(3('X(',i1,'):',
*     +       f12.2,2x))/5x,'Velocity:  ',3('X(',i1,'):',f9.4,5x))')ics,
*     +       int(qset(ntry7+10)),qset(ntry6+7),tnow,
*     +       (j2,vr1(j2),j2=1,3),(j2,vr2(j2),j2=1,3)
                  call los(vb1,vr1,xlos,rng,phi)
                  if (rng.lt.trng) then
                    hlos(1) = xlos(1)
                    hlos(2) = xlos(2)
                    hlos(3) = 0
                    call unit(hlos,hlos)
                    call dot(vb3,hlos,dprod,c,theta)
                    phi = asin(vb2(3))*cos(theta)-asin(xlos(3))
            if (db(1))
      +       write(8,'(5x,'Red ',i2,'  Mission Code ',i3,'  Speed ',f7.2,
      +       ' fps,  Time ',f9.2/ 5x,'Position:  ',(3('X(',i1,'):',
      +       f12.2,2x))/5x,'Velocity:  ',3('X(',i1,'):',f9.4,5x))')ics,
      +       int(qset(ntry7+10)),qset(ntry6+7),tnow,
      +       (j2,vr1(j2),j2=1,3),(j2,vr2(j2),j2=1,3)
        cs3 = 'right'
        if (theta.gt.0) cs3 = ' left'
        cs4 = ' above'
        if (phi.gt..17453) cs4 = ' below'
        if (db(1))
      +   write(8,'(5x,'Range, Blue 1 to Red ',i2,' is ',f12.2,' feet')')
```

```
     +   ics,rng
       if (dt(1))
     +   write(8,'(5x,'Visual Detection, Red ',i2,' bears ',a5,
     +   ' of nose ',i3,' degrees.')')ics,cs3,int(theta*57.3)
       if (db(1))
     +   write(8,'(10x,'He is ',a6,' the wing line.')')cs4
*
*    Sectors are established around the
*    aircraft, roughly forward, side,
*    and tail, with different probabilities
*    of visual detection in each sector.
*
                if (redd) then
                  if (abs(theta).gt.2.09434) then
*
*  Rear sector, with probability of detection
*    below the stern of the aircraftr = 0.
*
                    pdv = .2
                    if (phi.gt..17453) pdv = 0
                    go to 11018
                  endif
*
*  Side sector.
*
                  if (abs(theta).gt.0.52356) then
                    pdv = .6
                    if (phi.gt..17453) pdv = .25
                    go to 11018
                  endif
                  pdv = .4
                  if (phi.gt..17453) pdv = .1
                  go to 11018
                endif
*
*  Probabilities are established for the Blue
*    aircraft.
*
                if (abs(theta).gt.2.6178) then
                  pdv = .2
                  if (phi.gt..17453) pdv = 0
                  go to 11018
                endif
                if (abs(theta).gt.0.52356) then
                  pdv = .6
                  if (phi.gt..17453) pdv = .25
                  go to 11018
                endif
                pdv = .5
                if (phi.gt..17453) pdv = .2
*
*   The probability of visual detection is
*     predicated on many factors, such as
*     range, relative position, and amount
```

```
*     of maneuvering.
*
11018          pdv1 = pdv * 6000 / rng
               if (redd) pdv1 = pdv1*2
               call dot (xlos,vr2,dprod,c,theta)
               fasp = abs(sin(theta)) + .25
               ftrn = .25
               if (abs(qset(ntry2+9)).gt.1.5) frtn = .75
               pdv2 = (fasp + ftrn) / 2.
               pdv = pdv1 * pdv2
               comp = unfrm(0.,1.,9)
               cs4 = '  is  '
               if (pdv.lt.comp) cs4 = 'is not'
               if (db(1))
     +   write(8,'(5x,'Probability of Visual Detection is ',f5.3,
     +     '. Random number is ',f5.3,'.'/7x,'Red ',
     +     i2,1x,a6,' detected.')')
     +     pdv,comp,ics,cs4
               if (pdv.lt.comp) go to 11050
*              if ((qset(ntry7+7).eq.1).or.(qset(ntry7+7).eq.3))
*    +           qset(ntry7+7) = 3
*              if (qset(ntry7+7).lt.1) qset(ntry7+7) = 2
*
*   The visually detected threats are filed
*    in a visual threat file.
*
               nred1 = nred1 + 1
               ics1 = ics
               rng1 = rng
               do  11024  j1 = 1,n2
                 if (rng1.lt.red1(j1)) then
                   temp1 = red1(j1)
                   itemp1 = ired1(j1)
                   red1(j1) = rng1
                   ired1(j1) = ics1
                   rng1 = temp1
                   ics1 = itemp1
                   if (rng1.gt.trng) go to 11050
                 endif
11024          continue
             endif
11050          phi = asin(xlos(3) - vb2(3))
*     if (db(1))
*    +  write(8,'(5x,'Radar range, Blue 1 to Red ',i2,' is ',
*    +  f12.2,' feet')')ics,rng
*     if (db(1))
*    +  write(8,'(5x,'Radar detection limits are:  '/7x,'Elevation:  ',
*    +  'Upper  ',f7.2,' degrees, Lower ',f7.2,' degrees.'/7x,'Target ',
*    +  'elevation is ',f7.2,' degrees.')')upel*57.3,lowel*57.3,phi*57.3
               if ((phi.gt.lowel).or.(phi.lt.upel)) go to 10024
*
*   The targets are tested against a probability
*     of detection to see if they are detected
*     and filed in the aircraft's radar contact
```

```
*     file.  Targets are placed in the file in
*     order of closest range.
*
               xlos(3) = 0
               call unit(xlos,xlos)
               call dot(vh3,xlos,dprod,c,theta)
*     if (do(1))
*    +  write(8,'(5x,'Azimuth limits are: +/- ',f6.2,' degrees. ',
*    +  'Target azimuth ',f7.2,' degrees.')')azlmt*57.3,theta*57.3
               if (abs(theta).gt.azlmt) go to 10024
               pdr = 1.0
               if (rng.gt.150000) pdr = (270000.-rng)/120000.
               if (pdr.lt.0) pdr = 0
               if (redd) then
                 if ((phi.gt..17452).and.(vr1(2).gt.-10000)) pdr = .5 * pdr
               endif
               comp=unfrm(0.,1.,9)
               cs4 = '  is  '
               if (pdr.lt.comp) cs4 = 'is not'
*              if (db(1))
*    +   write(8,'(5x,'Probability of Radar Detection is ',f5.3,
*    +     '. Random number is ',f5.3,'.'/7x,'Red ',
*    +     i2,1x,a6,' detected.')')
*    +     pdr,comp,ics,cs4
               if (pdr.lt.comp) go to 10024
               nred = nred+1
*
*    The total number of threats and the ten
*      closest threats (radar contact) are
*      saved.
*              if (qset(ntry7+7).lt.2) qset(ntry7+7) = 1
*              if (qset(ntry7+7).gt.1) qset(ntry7+7) = 3
               do  10022  j1 = 1,n2
                 if (rng.lt.red(j1)) then
                   temp = red(j1)
                   itemp= ired(j1)
                   red(j1) = rng
                   ired(j1) = ics
                   rng = temp
                   ics = itemp
                   if (rng.gt.500000) go to 10024
                 endif
10022          continue
             endif
10024        ntry6 = nsucr(ntry6)
             ntry7 = nsucr(ntry7)
10026      continue
           if (redd) then
             do  10040  j1 = 1,11
               thtrr(n1,j1) = 999999
               itrr(n1,j1) = 0
10040        continue
             ntrr(n1) = nred
             vtrr(n1) = red1(1)
```

```
                ivtrr(n1) = ired1(1)
                if (qset(ntry2+7).gt.0) then
                  nred = min(10,nred)
                  do  10042  j1 = 1,nred
                    thtrr(n1,j1) = red(j1)
                    itrr(n1,j1) = ired(j1)
10042             continue
                  thtrr(n1,11) = thtrr(n1,1)
                  itrr(n1,11) = itrr(n1,1)
                endif
                go to 10032
              endif
              do  10028  j1 = 1,11
                thrt(n1,j1) = 999999
                ithrt(n1,j1) = 0
10028         continue
              nthrt(n1) = nred
              vthrt(n1) = red1(1)
              ivthrt(n1) = ired1(1)
              nred = min(10,nred)
              do  10030  j1 = 1,nred
                thrt(n1,j1) = red(j1)
                ithrt(n1,j1) = ired(j1)
10030         continue
              thrt(n1,11) = thrt(n1,1)
              ithrt(n1,11) = ithrt(n1,1)
10032         n5 = qset(ntry2+9)
              n6 = qset(ntry2+10)
              if (db(1))
     1          write(8,'(5x,'Visual Threat: ',a5,i3,
     2            5x,', Call Sign is: ',5x,i4,5x,
     3            ', Range is: ',7x,f15.2)')cs1,n1,
     4            ivthrt(n1),vthrt(n1)
              if ((db(4)).and.(redd)) then
                  write(8,'(5x,'Ntrr Red(',i2,') = ',i5,10x,'Time:  ',f8.2,
     2            5x,'Flag = ',i3,',  Msn Code = ',i4)')n1,ntrr(n1),
     3            tnow,n5,n6
                  write(8,'(5x,'Threat Call Signs are:',5x,5(i4,10x))')
     1              itrr(n1,11),(itrr(n1,j1),j1=2,5)
                  write(8,'(5x,'Threat Ranges are:',7x,5(f15.2)/)')
     1              thtrr(n1,11),(thtrr(n1,j1),j1=2,5)
                go to 10034
              endif
*             if (db(1)) then
*               write(8,'(5x,'Nthrt Blue(',i2,') = ',i5,10x,'Time:  ',f8.2,
*    2          5x,'Flag = ',i3,',  Msn Code = ',i4)')n1,nthrt(n1),
*    3          tnow,n5,n6
*               write(8,'(5x,'Threat Call Signs are:',2x,5(i2,9x))')
*    1            ithrt(n1,11),(ithrt(n1,j1),j1=2,5)
*               write(8,'(5x,'Threat Ranges are:',5(f11.2)/)')
*    1            thrt(n1,11),(thrt(n1,j1),j1=2,5)
*             endif
10034     ntry1 = nsucr(ntry1)
          ntry2 = nsucr(ntry2)
```

```
10036 continue
      if (redd) then
        call schdl(10,5.,atrib)
        return
      endif
      db(1) = .false.
      redd = .true.
      lowel = 4./57.3
      upel = -8./57.3
      azlmt = 40./57.3
      trng = 60000
      cs1 = ' Red'
      cs2 = 'Blue'
      n4 = nb
      n3 = nr
      n16 = 1
      n17 = 2
      ntry1 = mmfe(6)
      ntry2 = mmfe(7)
      ntry6 = mmfe(1)
      ntry7 = mmfe(2)
      go to 10008
      end
```

```
      subroutine cmp10(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*    i1:  aircraft callsign
*    n2:  mission code derivative
*    n3:  wingman's call sign
*    n4:  blue/red file pointer
*
***********************************************************************
*                                                                     *
*  This section flys Blue aircraft around the CAP patterns and        *
*    commits them on targets as appropriate.                          *
*                                                                     *
***********************************************************************
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  vec(3),vec1(3),vec2(3),uvec(3),flos(3),
     1 tlos(3),vb1(3),vb2(3),vr1(3),vr2(3)
      if (db(10)) write(8,'(5x,'Cmp10, Time ',f9.2)')tnow
      db(1) = .false.
*     if (i1.eq.1) db(1) = .true.
*
*  A check is made here for visually detected targets
*
      if (n4.eq.0) then
        ntry1 = locat(i1,1)
        ntry2 = locat(i1,2)
        n5 = ivthrt(i1)
        if (n5.le.0) go to 150
        n7 = locat(n5,7)
        if (qset(n7+10).lt.111) then
          ivthrt(i1) = 0
          vthrt(i1) = 999999
          go to 150
        endif
*
*
*  If the visually detected target is also
*    a radar contact to which the pilot is
*    locked up, the visual routine ignores
*    it.
*
        if (db(5))
     +   write(8,'(5x,'Blue ',i3,' has tally-ho on Red ',i3,' at Time'
     +   ,f9.2)')i1,ivthrt(i1),tnow
        ntry6 = locat(ivthrt(i1),6)
        do  112  j1 = 1,3
```

```
          vb1(j1)= qset(ntry1+j1)
          vb2(j1) = qset(ntry1+3+j1)
          vr1(j1) = qset(ntry6+j1)
          vr2(j1) = qset(ntry6+3+j1)
 112    continue
*
*   If the pilot is reacting to a visual
*     threat he tries to turn hard and
*     point at him in order to use his
*     weapons.
*
        call los(vr1,vb1,tlos,xmag,phi)
        n5 = qset(ntry2+1)
        if (n5.gt.0) then
          n7 = locat(n5,2)
          qset(n7+1) = 0
          qset(n7+6) = 1
        endif
        qset(ntry2+1) = 0
        qset(ntry2+6) = 1
        qset(ntry2+7) = xmag
        n2 = 11
        qset(ntry2+10) = 121
        qset(ntry2+9) = 4
        if (db(5))
     +    write(8,'(5x,'Blue ',i3,' reacting visually to  '
     +    'Red ',i2,',  Time ',f9.2)')i1,ivthrt(i1),tnow
        call cmp110(i1,n2,n3,n4)
        return
      endif
 150  continue
*
*  Section 1000 is the CAP section which keeps the aircraft
*    assigned to CAPs in their proper patterns.
*
*  QSET(NTRY2+9):  -2 => Straight Out
*                  -1 => Turn Out
*                   0 => Not Used
*                   1 => Turn In
*                   2 => Straight In
*                   3 => Initial Pass Through This Section
*                   4 => Departing Base
*
 1000 ntry1 = locat(i1,1)
      ntry2 = locat(i1,2)
      qset(ntry1+9) = 585
      qset(ntry1+10) = 20000
*
*  Desired airspeed and altitude are set to
*    CAP airspeed and altitude.
*
      if (qset(ntry2+6).eq.2) then
*
*  If there is a wingman, he is positioned 45 degrees
```

```
*    back and 3000' out.
*
        n7 = qset(ntry2+1)
        n5 = locat(n7,1)
        n6 = locat(n7,2)
        x1 = 3000*(cos(135./57.3)*qset(n5+4)-sin(135./57.3)*
     +    qset(n5+5))
        x2 = 3000*(sin(135./57.3)*qset(n5+4)+cos(135./57.3)*
     +    qset(n5+5))
        qset(ntry1+1) = qset(n5+1)+x1
        qset(ntry1+2) = qset(n5+2)+x2
        qset(ntry1+3) = qset(n5+3)
        qset(ntry1+4) = qset(n5+4)
        qset(ntry1+5) = qset(n5+5)
        qset(ntry1+6) = qset(n5+6)
*       if (qset(ntry2+9).ne.qset(n6+9))
*    +    write(8,'(5x,'Blue 2, CAP #',i1,', Speed ',f7.2,', Time ',
*    + f9.2/5x,'Position:  ',3('X(',i1,'):',f13.2,2x)/5x,'Velocity:  ',
*    + 3('X(',i1,'):',3x,f8.4,4x))')n2,qset(ntry1+7),tnow,
*    + (j2,qset(ntry1+j2),j2=1,3),(j2,qset(ntry1+3+j2),j2=1,3)
        qset(ntry2+9) = qset(n6+9)
        qset(ntry2+10) = qset(n6+10)
        return
      endif
      if (thrt(i1,1).le.200000) then
    4   n6 = locat(ithrt(i1,1),6)
        n7 = locat(ithrt(i1,1),7)
        if  (qset(n7+10).lt.111) then
          do 6 j2 =  1,9
            ithrt(i1,j2) = ithrt(i1,j2+1)
            thrt(i1,j2) = thrt(i1,j2+1)
    6     continue
          ithrt(i1,10) = 0
          thrt(i1,10) = 999999
          ithrt(i1,11) = ithrt(i1,1)
          thrt(i1,11) = thrt(i1,1)
          nthrt(i1) = nthrt(i1) - 1
          if (nthrt(i1).gt.0) go to 4
          go to 8
        endif
        if (qset(n6+2).gt.10389200) go to 8
*
*  Aircraft from CAPs 1 and 3 commit first, on
*     targets within 40 NM.  CAP 3 commits on
*     targets within 30 NM.
*
        qset(ntry2+9) = 1
        ncap(n2) = ncap(n2)-1
        if (qset(ntry2+1).ne.0) ncap(n2) = ncap(n2)-1
        if (db(5))
     +    write(8,'(5x,'Blue ',i3,' committed from CAP ',i2,', Time:'
     +      ,f8.2)')i1,n2,tnow
        n2 = 10
        call cmp100(i1,n2,n3,n4)
```

```
          return
        endif
      8 ntry5 = locat(n2,5)
        do  10  j1 = 1,3
          vec2(j1) = qset(ntry5+j1)
          vec1(j1) = qset(ntry1+j1)
          vec(j1) = qset(ntry1+3+j1)
   10 continue
          if (qset(ntry2+9).gt.3.5) then
*
*  Aircraft is departing base
*
            if (db(5))
     +        write(8,'(5x,'Blue ',i3,' departed base at Time ',f7.2,
     +        ' for CAP',i3)')i1,tnow,n2
            call los(vec1,vec2,flos,xmag,phi)
*
*  Establish Line-of-Sight vector from PP to CAP Point
*
            qset(ntry2+9) = 2
            qset(ntry1+7) = 585
            qset(ntry1+9) = 585
            qset(ntry1+10) = qset(ntry5+3)
            uvec(1) = flos(1)*cos(-10./57.3)
            uvec(2) = flos(2)*cos(-10./57.3)
            uvec(3) = sin(-10./57.3)
            call unit(uvec,uvec)
            do  14  j1 = 1,3
              qset(ntry1+3+j1) = uvec(j1)
   14       continue
            go to 30
          endif
        if (qset(ntry2+9).gt.2.5) then
*
*  This is first time into
*    Subroutine Compute on CAP assignment.
*
          call los(vec1,vec2,flos,xmag,phi)
          qset(ntry2+9) = 1
          qset(ntry1+9) = 585
          qset(ntry1+10) = qset(ntry5+3)
          ncap(n2) = ncap(n2)+1
          if (qset(ntry2+1).gt.0) ncap(n2) = ncap(n2) + 1
        endif
        call los(vec1,vec2,flos,xmag,phi)
*
*  Check to see if aircraft outbound in CAP
*    has reached the far end.
*
        if  ((qset(ntry2+9).lt.-1.5).and.(xmag.gt.72000)) then
        if (db(1))
     +  write(8,'(5x,'Blue 1, CAP #',i1,', Speed ',f7.2,', Time ',
     +  f9.2/5x,'Position:  ',3('X(',i1,'):',f13.2,2x)/5x,'Velocity:  ',
     +  3('X(',i1,'):',3x,f8.4,4x))')n2,qset(ntry1+7),tnow,
```

```
         +  (j2,vec1(j2),j2=1,3),(j2,vec(j2),j2=1,3)
          if (db(1))
         +  write(8,'(5x,'CAP ',i1,' range is ',f5.1,' NM'/10x,'CAP ',
         +  i1,' location is ',3('X(',i1,'):',f13.2,2x))')n2,
         +  xmag/6000.,n2,(j2,vec2(j2),j2=1,3)
            qset(ntry2+9) = 1
*           if (db(5))
*        +  write(8,'(5x,'Blue ',i2,' turning inbound  in CAP ',i1,
*        +    ', Time:  ',f8.2)')i1,n2,tnow
            go to 30
          endif
*
*   Check to see if aircraft inbound to CAP
*     has arrived.
*
          if  ((qset(ntry2+9).gt.1.5).and.(xmag.le.3000)) then
          if (db(1))
         +  write(8,'(5x,'Blue 1, CAP #',i1,', Speed ',f7.2,', Time ',
         +  f9.2/5x,'Position:  ',3('X(',i1,'):',f15.2)/5x,'Velocity:  ',
         +  3('X(',i1,'):',3x,f8.4,4x))')n2,qset(ntry1+7),tnow,
         +  (j2,vec1(j2),j2=1,3),(j2,vec(j2),j2=1,3)
          if (db(1))
         +  write(8,'(5x,'CAP ',i1,' range is ',f5.1,' NM'/10x,'CAP ',
         +  i1,' location is ',3('X(',i1,'):',f15.2))')n2,
         +  xmag/6000.,n2,(j2,vec2(j2),j2=1,3)
            qset(ntry2+9) = -1
*           if (db(5))
*        +  write(8,'(5x,'Blue ',i2,' turning outbound in CAP ',i2,
*        +    ', Time ',f7.2)')i1,n2,tnow
            go to 30
          endif
          if (abs(qset(ntry2+9)).gt.1.5) go to 30
*
*   Check to see if aircraft turning
*     inbound have completed the turn.
*
          if (qset(ntry2+9).gt.0) then
            call los(vec1,vec2,flos,xmag,phi)
            call dot(vec,flos,dprod,c,theta)
            if (abs(theta).lt.(10./57.3)) then
              do  20  j1 = 1,3
                qset(ntry1+3+j1) = flos(j1)
   20         continue
              qset(ntry2+9) = 2
          if (db(1))
         +  write(8,'(5x,'Blue 1, CAP #',i2,', Speed ',f7.2,', Time ',
         +  f9.2/5x,'Position:  ',3('X(',i2,'):',f15.2)/5x,'Velocity:  ',
         +  3('X(',i2,'):',3x,f8.4,4x))')n2,qset(ntry1+7),tnow,
         +  (j2,vec1(j2),j2=1,3),(j2,vec(j2),j2=1,3)
          if (db(1))
         +  write(8,'(5x,'CAP ',i1,' range is ',f5.1,' NM'/10x,'CAP ',
         +  i1,' location is ',3('X(',i1,'):',f15.2))')n2,
         +  xmag/6000.,n2,(j2,vec2(j2),j2=1,3)
*             if (db(5))
```

```
*    +    write(8,'(5x,'Blue ',i2,' headed inbound to CAP ',i1,
*    +       ', Time:  ',f8.2)')i1,n2,tnow
          go to 30
        endif
        call turn(vec,flos,2.5,ntry1,dtnow,qset(ntry1+7))
        go to 30
      endif
      do  22  j1 = 1,3
        vec2(j1) = qset(ntry5+3+j1)
   22 continue
      vec2(3) = 0
      call unit(vec2,vec2)
      call dot(vec,vec2,dprod,c,theta)
*
*  If the turn is complete ,
*    assign the appropriate code.
*
      if (theta.lt.(5./57.3)) then
        qset(ntry2+9) = -2
      if (db(1))
     +  write(8,'(5x,'Blue 1, CAP #',i2,', Speed ',f7.2,', Time ',
     +  f9.2/5x,'Position:  ',3('X(',i2,'):',f15.2)/5x,'Velocity:  ',
     +  3('X(',i2,'):',3x,f8.4,4x))')n2,qset(ntry1+7),tnow,
     +  (j2,vec1(j2),j2=1,3),(j2,vec(j2),j2=1,3)
      if (db(1))
     +  write(8,'(5x,'CAP ',i1,' range is ',f5.1,' NM'/10x,'CAP ',
     +  i1,' location is ',3('X(',i1,'):',f15.2))')n2,
     +  xmag/6000.,n2,(j2,qset(ntry5+j2),j2=1,3)
*       if (db(5))
*    +  write(8,'(5x,'Blue ',i2,' headed outbound in CAP ',i1,
*    +     ', Theta = ',f8.4,', Time:  ',f8.2)')i1,n2,theta,tnow
        go to 30
      endif
      call turn(vec,vec2,2.5,ntry1,dtnow,qset(ntry1+7))
*
*  Level Off (if required)
*
*    Check to see if the aircraft is close
*      enough to his desired altitude to
*      begin to level off.
*
   30 delta = abs(qset(ntry1+10)-qset(ntry1+3))
      vvi = abs(0.6*qset(ntry1+6)*qset(ntry1+7))
      ddlta = max(1000./60.,vvi)
      if (delta.lt.ddlta) then
        sign = 1
        if (qset(ntry1+6).lt.0) sign = -1
        if (delta.lt.200) then
          qset(ntry1+6) = 0
        else
          qset(ntry1+6) = qset(ntry1+6)+ddlta*sign
        endif
        do  32  j1 = 1,3
          vec1(j1) = qset(ntry1+3+j1)
```

```
32    continue
      call unit(vec1,vec1)
      do  34  j1 = 1,3
        qset(ntry1+3+j1) = vec1(j1)
34    continue
    endif
    db(i) = .false.
    return
    end
```

```
      subroutine cmp40(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*    i1:  aircraft callsign
*    n2:  mission code derivative
*    n3:  wingman's call sign
*    n4:  blue/red file pointer
*
***********************************************************************
*                                                                     *
*  This section controls the Red Escort fighters.                     *
*                                                                     *
***********************************************************************
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  vec1(3),vec2(3),xlos(3),
     1 vb1(3),vb2(3),vb3(3),vr1(3),vr2(3),a(10)
      if (db(10)) write(8,'(5x,'Cmp40, Time ',f9.2)')tnow
4000 ntry6 = locat(i1,6)
      ntry7 = locat(i1,7)
      if (qset(ntry7+6).eq.2) return
      n5 = 0
      if (qset(ntry7+1).gt.0) then
        n5 = i1 + 1
        n6 = nsucr(ntry6)
        n7 = nsucr(ntry7)
        do 4010 j1 = 1,3
          vec1(j1) = qset(n6+j1)
          vec2(j1) = qset(n6+3+j1)
4010    continue
        if (qset(n7+9).eq.0) qset(n7+9) = 1
      endif
      if (qset(ntry7+9).eq.3) then
        ntry8 = locat(i1,8)
        if (qset(ntry8+1).le.0) then
          qset(ntry7+9) = 2
        endif
      endif
      if ((ntrr(i1).gt.0).and.(qset(ntry7+9).lt.1.5))
     +   qset(ntry7+9) = 2
      if (n5.gt.0) qset(n7+9) = 2
      do 4006 j1 = 1,3
        vr1(j1) = qset(ntry6+j1)
        vr2(j1) = qset(ntry6+3+j1)
4006 continue
      if (qset(ntry7+9).eq.0) qset(ntry7+9) =1
      if (qset(ntry7+8).eq.2) go to 4400
```

```
4300 if ((qset(ntry7+9).eq.3).or.(qset(ntry7+9).eq.2)) then
       n10 = itrr(i1,11)
       if (n10.lt.0.5) then
         qset(ntry7+9) = 1
         if (n5.gt.0) qset(n7+9) = 1
         do 4008 j1 = 1,11
           itrr(i1,j1) = 0
           thtrr(i1,j1) = 999999
4008     continue
         ntrr(i1) = 0
         go to 4100
       endif
       n11 = locat(n10,1)
       n12 = locat(n10,2)
       if (qset(n12+10).lt.111) then
         qset(ntry7+9) = 1
         if (n5.gt.0) qset(n7+9) = 1
         do 4310 j1 = 1,11
           itrr(i1,j1) = 0
           thtrr(i1,j1) = 999999
4310     continue
         ntrr(i1) = 0
         go to 4100
       endif
       do 4312 j1 = 1,3
         vb1(j1) = qset(n11+j1)
         vb2(j1) = qset(n11+3+j1)
4312   continue
       call los(vr1,vb1,xlos,xmag,phi)
       if ((qset(ntry7+9).eq.2).and.(xmag.lt.3000)) then
         qset(ntry7+9) = 1
         if (n5.gt.0) qset(n7+9) = 1
         do 4318 j1 = 1,11
           itrr(i1,j1) = 0
           thtrr(i1,j1) = 999999
4318     continue
         ntrr(i1) = 0
         go to 4100
       endif
       call dot(vr2,xlos,dprod,c,theta1)
       call dot(vb2,xlos,dprod,c,theta2)
       rtheta = atan(qset(ntry6+7)/(4.0*32.2))
       if (abs(theta1).lt.rtheta) then
         do 4314 j1 = 1.3
           qset(ntry6+3+j1) = xlos(j1)
4314     continue
       else
         call turn(vr2,xlos,4.0,ntry6,dtnow,qset(ntry6+7))
       endif
       if (n5.gt.0) then
         do 4320 j1 = 1,3
           qset(n6+3+j1) = qset(ntry6+3+j1)
4320     continue
       endif
```

```
      nb=24
      nr=80
*
*  'nb' and 'nr' are the number of Blue and the
*    number of Red aircraft available.
*
      do 32 j1 = 1,14
        xx(j1) = 0
   32 continue
      xx(1) = 4
      xx(2) = 16
*
*  XX(1) and XX(2) are the number of
*    Blue and Red aircraft involved
*    in the simulation run.
*
      blue(1) = 10e6
      blue(2) = 10e6
      blue(3) = 0
*
*  'blue' is an array which holds the coordinates
*      of the blue airrfield.
*
      a(1)=10e6
      a(2)=10e6
      do  12  j1 = 1,nb
        call filem(1,a)
 12   continue
*
*  The aero information and operational files
*     are initiallized with the values the
*     aircraft would have sitting on the base.
*
      a(1)=0
* The first element will be the wingman's call sign.
      a(2)=14500
*  Second:  fuel load in pounds.
      a(3)=4
*  Third:  number of radar missiles.
      a(4)=4
*  Fourth:  number of heatseeking (IR) missiles.
      a(5)=9
*  Fifth:  number of seconds of cannon fire.
      a(9)=4
*  Ninth:  mission flag (4 d% nroff -o,35- AppenC
```

```
          go to 4350
        endif
 4400   if ((qset(ntry7+9).eq.3).or.(qset(ntry7+9).eq.2)) then
          n10 = itrr(i1,11)
          if (n10.lt.0.5) then
            qset(ntry7+9) = 1
            if (n5.gt.0) qset(n7+9) = 1
            do 4408 j1 = 1,11
              itrr(i1,j1) = 0
              thtrr(i1,j1) = 999999
 4408       continue
            ntrr(i1) = 0
            go to 4100
          endif
          phi1 = 20./57.3
          phi2 = -20./57.3
          theta = 10/57.3
          n11 = locat(n10,1)
          n12 = locat(n10,2)
          if (qset(n12+10).lt.111) then
            qset(ntry7+9) = 1
            if (n5.gt.0) qset(n7+9) = 1
            do 4410 j1 = 1,11
              itrr(i1,j1) = 0
              thtrr(i1,j1) = 999999
 4410       continue
            ntrr(i1) = 0
            go to 4100
          endif
          do 4412 j1 = 1,3
            vb1(j1) = qset(n11+j1)
            vb2(j1) = qset(n11+3+j1)
 4412     continue
          call los(vr1,vb1,xlos,xmag,phi)
          call dot(vr2,xlos,dprod,c,theta1)
          call dot(vb2,xlos,dprod,c,theta2)
          rtheta = atan(qset(ntry6+7)/(4.0*32.2))
          if (xmag.le.60000) then
            if (abs(theta1).le.rtheta) then
              do 4414 j1 = 1,3
                qset(ntry6+3+j1) = xlos(j1)
 4414         continue
            else
              call turn(vr2,xlos,4.0,ntry6,dtnow,qset(ntry6+7))
            endif
            if (n5.gt.0) then
              ntrr(n5) = 1
              do 4416 j1 = 1,11
                thtrr(n5,j1) = 999999
                itrr(n5,j1) = 0
 4416         continue
              itrr(n5,1) = itrr(i1,1)
              itrr(n5,11) = itrr(i1,1)
              thtrr(n5,1) = thtrr(i1,1)
```

```
                thtrr(n5,11) = thtrr(i1,1)
                call los(vec1,vb1,xlos,xmagi,phi)
                call dot(vec2,xlos,dprod,c,theta1)
                if (abs(theta1).le.rtheta) then
                  do 4428 j1 = 1,3
                    qset(n6+3+j1) = xlos(j1)
 4428             continue
                else
                  call turn(vec2,xlos,4.0,n6,dtnow,qset(ntry6+7))
                endif
              endif
              go to 4350
            endif
            if (xmag.le.120000) then
              vb3(1) = xlos(1) * cos(theta) + xlos(2) * sin(phi1)
              vb3(2) = xlos(1) * (-cos(theta)) * sin(phi1) + xlos(2) *
     +              cos(theta) *  cos(phi1) + xlos(3) * sin(theta)
              vb3(3) = xlos(1) * sin(theta) * sin(phi1) +xlos(2) *
     +             (-sin(theta)) * cos(phi1) + xlos(3) * cos(theta)
              call unit(vb3,vb3)
              call dot(vr2,vb3,dprod,c,theta1)
              rtheta = atan(qset(ntry6+7)/(4.0*32.2))
              if (abs(theta1).le.rtheta) then
                do 4422 j1 = 1,3
                  qset(ntry6+3+j1) = vb3(j1)
 4422           continue
              else
                call turn(vr2,vb3,4.0,ntry6,dtnow,qset(ntry6+7))
              endif
              if (n5.gt.0) then
                call los(vec1,vb1,xlos,xmag,phi)
                call dot(vec2,xlos,dprod,c,theta1)
                vb1(1) = xlos(1) * cos(theta) + xlos(2) * sin(phi2)
                vb1(2) = xlos(1) * (-cos(theta)) * sin(phi2) + xlos(2) *
     +              cos(theta) *  cos(phi2) + xlos(3) * sin(theta)
                vb1(3) = xlos(1) * sin(theta) * sin(phi2) +xlos(2) *
     +             (-sin(theta)) * cos(phi2) + xlos(3) * cos(theta)
                call unit(vb1,vb1)
                call dot(vec2,vb1,dprod,c,theta3)
                if (abs(theta3).le.rtheta) then
                  do 4426 j1 = 1,3
                    qset(n6+3+j1) = vb1(j1)
 4426             continue
                else
                  call turn(vec1,vb1,4.0,n6,dtnow,qset(n6+7))
                endif
              endif
            endif
          endif
 4350     if (qset(ntry7+9).eq.3) return
          if (qset(ntry7+9).eq.2) then
            rmax = 15000 +108000 * sin(abs(theta2/6))
            rmin = 6000 + 10000 * sin(abs(theta2/3))
            htmax = 6000 - qset(ntry6+3)/4
```

```
      ntmin = 1500 +3000 * sin(abs(theta2))
      if (abs(theta2).gt.(45./57.3)) htmin = htmax
      if ((xmag.gt.htmin) .and.(xmag.lt.htmax)) then
        if (abs(theta2).lt.(45./57.3).and.(qset(ntry7+4).gt.0))
     +    then
          if (abs(theta1).lt.(10./57.3)) then
            qset(ntry7+4) = qset(ntry7+4) - 1
            qset(ntry7+9) = 1
            do 4330 j1 = 1,3
              a(j1) = qset(ntry6+j1)
              a(j1+3) = qset(ntry6+3+j1)
 4330       continue
            a(7) = qset(ntry6+7) + 1000
            a(8) = 22
            a(9) = n10
            a(10) = xmag
            call filem(9,a)
            write(8,'(5x,'Red ',i3,' launched heatseeker at ',
     +        'Blue ',i3,' Time ',f9.2)')i1,n10,tnow
            xx(14) = xx(14) + 1
            qset(ntry7+9) = 1
            if (n5.gt.0) qset(n7+9) = 1
            do 4332 j1 = 1,11
              itrr(i1,j1) = 0
              thtrr(i1,j1) = 999999
 4332       continue
            ntrr(i1) = 0
            go to 4100
          endif
        endif
      endif
      if ((qset(ntry7+3).gt.0).and.(qset(ntry7+9).ne.3)) then
      if ((xmag.gt.rmin).and.(xmag.lt.rmax)) then
        if ((phi.gt.0.17452).and.(qset(ntry6+3).gt.-10000))
     +    return
        if (abs(theta1).le..34904) then
          do 4334 j1 = 1,3
            a(j1) = qset(ntry6+j1)
            a(j1+3) = qset(ntry6+3+j1)
 4334     continue
          a(7) = qset(ntry6+7) + 1100
          a(8) = 90
          a(9) = n10
          a(10) = xmag
          ntry8 = locat(i1,8)
          do 4336 j1 = 1,10
            qset(ntry8+j1) = a(j1)
 4336     continue
          write(8,'(5x,'Red ',i3,' launched radar missile at ',
     +      'Blue ',i3,' Time ',f9.2)')i1,n10,tnow
          qset(ntry7+3) = qset(ntry7+3) - 1
          qset(ntry7+9) = 3
          xx(13) = xx(13) + 1
          if ((n5.gt.0).and.(itrr(n5,11).eq.itrr(i1,11))) then
```

```
                do 4340 j1 = 1,3
                  vr1(j1) = qset(n6+j1)
                  vr2(j1) = qset(n6+3+j1)
 4340           continue
                call los(vr1,vb1,xlos,xmag,phi)
                if ((xmag.gt.rmin).and.(xmag.lt.rmax)) then
                  if ((phi.gt.0.17452).and.(qset(n6+3).gt.-10000))
     +            return
                  if (qset(ntry7+3).le.0) return
                  if (qset(ntry7+9).eq.3) return
                  if (abs(theta1).le..34904) then
                    do 4342 j1 = 1,3
                      a(j1) = qset(n6+j1)
                      a(j1+3) = qset(n6+3+j1)
 4342               continue
                    a(7) = qset(n6+7) + 1100
                    a(8) = 90
                    a(9) = n10
                    a(10) = xmag
                    ntry8 = nsucr(ntry8)
                    do 4338 j1 = 1,3
                      qset(ntry8+j1) = a(j1)
 4338               continue
                    write(8,'(5x,'Red ',i3,' also launched radar '
     +              'missile at Blue ',i3,' Time ',f9.2)')n5,n10,tnow
                    qset(n7+9) = qset(n7+3) - 1
                    qset(n7+9) = 3
                    xx(13) = xx(13) + 1
                  endif
                endif
                return
              endif
            endif
          endif
        endif
        endif
 4100   if (qset(ntry7+9).lt.1.5) then
          if (qset(ntry7+7).eq.1) then
            do 4110 j1 = 1,3
              vb1(j1) = blue(j1)
 4110       continue
            call los(vr1,vb1,xlos,xmag,phi)
            call dot(vr2,xlos,dprod,c,theta)
            xlos(3) = 0
            call unit(xlos,xlos)
            rtheta = atan(qset(ntry6+7)/(3.5*32.2))
            if (abs(theta).le.rtheta) then
              do 4112 j1 = 1,3
                qset(ntry6+3+j1) = xlos(j1)
 4112         continue
            else
              call turn(vr2,xlos,3.5,ntry6,dtnow,qset(ntry6+7))
            endif
            if (qset(ntry7+6).eq.1)  then
```

```
            if (xmag.lt.72000) then
              qset(ntry7+7) =2
              if (n5.gt.0) qset(n7+7) = 2
            endif
          endif
        endif
        if (qset(ntry7+7).eq.2) then
          if (xmag.lt.30000) then
            qset(ntry7+10) = 100
            write(8,'(5x,'Red ',i3,' landed, Time ',f9.2)')i1,tnow
            if (n5.gt.0) then
              qset(n7+10) = 100
              write(8,'(5x,'Red ',i3,' landed, Time 'f9.2)')
     +          n5,tnow
            endif
            return
          endif
          n8 = 1
          if (i1.gt.40) n8 = 2
          do 4116 j1 = 1,3
            vb1(j1) = redb(n8,j1)
4116      continue
          call los(vr1,vb1,xlos,xmag,phi)
          call dot(vr2,xlos,dprod,c,teta)
          rtheta = atan(qset(ntry6+7)/(3.5*32.2))
          if (abs(theta).le.rtheta) then
            do 4118 j1 = 1,3
              qset(n6+3+j1) = qset(ntry6+3+j1)
4118        continue
        endif
      endif
      endif
      if (n5.gt.0) then
        if ((qset(ntry7+8).eq.2).and.(n5.gt.0)) then
          call los(vr1,vec1,xlos,xmag,phi)
          if (xmag.gt.2000) then
            call dot(vec2,xlos,dprod,c,theta1)
            if (abs(theta1).le.rtheta) then
              do 4120 j1 = 1,3
                qset(n6+3+j1) = xlos(j1)
4120          continue
            else
              call turn(vec2,xlos,4.0,n6,dtnow,qset(n6+7))
              qset(n6+9) = qset(ntry6+7) * 1.2
            endif
            return
          else
            qset(n6+7) = qset(ntry6+7)
            qset(n6+9) = qset(ntry6+9)
          endif
        do 4114 j1 = 1,3
          qset(n6+3+j1) = qset(ntry6+3+j1)
4114    continue
      endif
```

```
endif
return
end
```

```
      subroutine cmp60(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*    i1:  aircraft callsign
*    n2:  mission code derivative
*    n3:  wingman's call sign
*    n4:  blue/red file pointer
*
************************************************************************
*                                                                      *
*  This subroutine flys heatseeking (IR) missiles out                  *
*    to targets and determines whether the target is killed.           *
*                                                                      *
************************************************************************
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      character cs1*4,cs2*4,cs3*6
      dimension  flos(3),
     1 vb1(3),vb2(3),vr1(3),vr2(3)
      if (db(10)) write(8,'(5x,'Cmp60, I1 ',i3,
     + ',  Time ',f9.2)')i1,tnow
6000  ntry4 = mmle(i1)
        nn4 = nnq(i1)
        n7 = 6
        n8 = 7
        cs1 = 'Blue'
        cs2 = ' Red'
        cs3 = 'is not'
        if (i1.eq.9) then
          n7 = 1
          n8 = 2
          cs1 = ' Red'
          cs2 = 'Blue'
        endif
        do  42  j1 = nn4,1,-1
          ics = qset(ntry4+9)
*         write(8,'(5x,'Heat missile section, ICS = ',i4,', J1 = ',i3,
*    +      ', N7 ',i3,', N8 ',i3)')
*    +       ics,j1,n7,n8
          ntry6 = locat(ics,n7)
          ntry7 = locat(ics,n8)
*         if (tnow.ge.1000) write(8,'(5x,'Point 1')')
          if (qset(ntry7+10).lt.111) then
            write(8,'(5x,'Heatseeker gone ballistic, Target ',a4,
     +        2x,i2,' already dead.')')cs2,ics
            call ulink(j1,i1)
            go to 6048
```

```
            endif
*           if (tnow.ge.1000) write(8,'(5x,'Point 2')')
            do  44  j2 = 1,3
              vb1(j2) = qset(ntry4+j2)
              vb2(j2) = qset(ntry4+3+j2)
              vr1(j2) = qset(ntry6+j2)
              vr2(j2) = qset(ntry6+3+j2)
   44       continue
*           if (tnow.ge.1000) write(8,'(5x,'Point 3')')
            call los(vb1,vr1,flos,xmag,phi1)
            call dot(vb2,vr2,dprod,c,theta3)
            vel = qset(ntry4+7)
*           if (tnow.ge.1000) write(8,'(5x,'Point 4')')
            do  46  j2 = 1,3
              qset(ntry4+3+j2) = flos(j2)
              qset(ntry4+j2) = qset(ntry4+j2)+qset(ntry4+3+j2)*vel*dtnow
              vb1(j2) = qset(ntry4+j2)
   46       continue
*       if (i1.eq.4)
*     +  write(8,'(5x,'Heat missile section, Target is ',a5,i3,
*     +     ' Speed ',f7.2,' fps, Time ',f7.2)')cs2,ics,vel,tnow
*       if (i1.eq.4)
*     +  write(8,'(5x,'Missile position:  ',3('X(',i1,'):',f15.2)/
*     +  13x,'Velocity:  ',3('X(',i1,'):',2x,f9.4,4x))')
*     +  (j2,vb1(j2),j2=1,3),(j2,vb2(j2),j2=1,3)
*       if (i1.eq.4)
*     +  write(8,'(5x,' Target position:  ',3('X(',i1,'):',f15.2)/
*     +  13x,'Velocity:  ',3('X(',i1,'):',2x,f9.4,4x))')
*     +  (j2,vr1(j2),j2=1,3),(j2,vr2(j2),j2=1,3)
*
*  The IR missile calculations are simpler
*     because it uses a simple pure pursuit
*     instead of intercept headings.
*
            call los(vb1,vr1,flos,xmag,phi)
*           if (tnow.ge.1000) write(8,'(5x,'Point 5')')
            comp = qset(ntry4+10) - xmag
*       if (i1.eq.4)
*     +  write(8,'(5x,'Previous range:  ',f10.2,', Current Range:  ',
*     +  f10.2,' Delta:  ',f7.1)')qset(ntry4+10),xmag,comp
            if (comp.lt.0) then
              comp = unfrm(0.,1.,9)
              if (i1.eq.4) then
*           if (tnow.ge.1000) write(8,'(5x,'Point 7')')
                pk = .75
                if (comp.lt.pk) then
                  cs3 = '  is  '
                  qset(ntry7+10) = 103
                  qset(ntry7+9) = 0
                  qset(ntry7+8) = tnow
*           if (tnow.ge.1000) write(8,'(5x,'Point 8')')
                  n5 = qset(ntry7+1)
                  if (n5.gt.0) then
                    n9 = locat(n5,7)
```

```
                 qset(n9+6) = 1
                 qset(n9+1) = 0
               endif
*          if (tnow.ge.1000) write(8,'(5x,'Point 9')')
               call ulink(j1,i1)
*      if (i1.eq.4)
*     +  write(8,'(5x,'Missile passed target, kill determination:  '/
*     +  15x,'Pk = ',f6.4,', Random Number = ',f6.4,', Target ',a6,
*     +  ' dead.')')pk.comp,cs3
               if (db(5))
     +         write(8,'(5x,'Red ',i3,' shot down by heatseeker at ',
     +           'coord N',f12.2,', E',f12.2,' Time: ',f12.2)')ics,
     +           qset(ntry6+1),qset(ntry6+2),tnow
               xx(4) = xx(4) + 1
               xx(8) = xx(8) + 1
               go to 6048
             else
               call ulink(j1,i1)
               cs3 = 'is not'
*      if (i1.eq.4)
*     +  write(8,'(5x,'Missile passed target, kill determination:  '/
*     +  15x,'Pk = ',f6.4,', Random Number = ',f6.4,', Target ',a6,
*     +  ' dead.')')pk,comp,cs3
               if (db(5))
     +         write(8,'(5x,'Red ',i4,' survived heat missile shot. ',
     +           ' Time ',f12.2)')ics,tnow
               go to 6048
             endif
*
*   Just as for the radar missile, a pk
*     is calculated at the point of closest
*     approach, and compared with a random
*     to determine missile success or failure.
*
           endif
           if (i1.eq.9) then
*          if (tnow.ge.1000) write(8,'(5x,'Point 10')')
             pk = .4
             if (comp.lt.pk) then
*          if (tnow.ge.1000) write(8,'(5x,'Point 11')')
               n5 = qset(ntry7+1)
               if (n5.gt.0) then
                 n9 = locat(n5,2)
                 qset(n9+6) = 1
                 qset(n9+1) = 0
               endif
*          if (tnow.ge.1000) write(8,'(5x,'Point 12')')
               qset(ntry7+10) = 103
               qset(ntry7+9) = 0
               qset(ntry7+8) = tnow
               call ulink(j1,i1)
               if (db(5))
     +         write(8,'(5x,'Blue ',i3,' shot down by heatseeker at ',
     +           'coord N',f12.2,', E',f12.2,' Time: ',f12.2)')ics,
```

```
     +            qset(ntry6+1),qset(ntry6+2),tnow
                xx(3) = xx(3) + 1
                xx(6) = xx(6) + 1
                go to 6048
              else
                call ulink(j1,i1)
                if (db(5))
     +          write(8,'(5x,'Blue',i4,' survived heat missile shot, ',
     +            ' Time_',f12.2)')ics,tnow
                go to 6048
              endif
            endif
*
*  Just as for the radar missile, a pK
*    is calculated at the point of closest
*    approach, and compared with a random
*    to determine missile success or failure.
*
          endif
          qset(ntry4+10) = xmag
          qset(ntry4+8) = qset(ntry4+8)-dtnow
          if (qset(ntry4+8).le.0) then
            call ulink(j1,i1)
            write(8,'(5x,'IR missile self-destruct at end of flight ',
     +        'time, Time:  ',f12.2)')tnow
            go to 6048
          endif
6048      ntry4 = npred(ntry4)
*         write(8,'(5x,'Cmp60, Bottom, Ntry4 = ',i6)')ntry4
          if (ntry4.eq.0) return
  42    continue
      return
      end
```

```
      subroutine cmp70(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*    i1:  aircraft callsign
*    n2:  mission code derivative
*    n3:  wingman's call sign
*    n4:  blue/red file pointer
*
*************************************************************************
*                                                                       *
*             This section flys out radar missiles and                  *
*               determines their success or failure                     *
*               after tney reach the target.                            *
*                                                                       *
*************************************************************************
*
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      character cs1*4,cs2*4
      dimension  uvec1(3),flos(3),
     1 tlos(3),vb1(3),vb2(3),vr1(3),vr2(3),vr3(3)
      if (db(10)) write(8,'(5x,'Cmp70, Time ',f9.2)')tnow
7000      ntry3 = locat(i1,n4)
          if (n4.eq.3) then
            ntry1 = locat(i1,1)
            ntry2 = locat(i1,2)
            n11 = 1
            n12 = 2
            cs1 = 'Blue'
            cs2 = ' Red'
            n16 = 6
            n17 = 7
          endif
          if (n4.eq.8) then
            n11 = 6
            n12 = 7
            n16 = 1
            n17 = 2
            cs1 = ' Red'
            cs2 = 'Blue'
            ntry1 = locat(i1,6)
            ntry2 = locat(i1,7)
          endif
          ics = qset(ntry3+9)
*         if ((db(5)).and.(tnow.gt.830))
*    +    write(8,'(5x,'Radar missile section, ICS = ',i3,
*    +      ', QSET(NTRY3+9) = ',i5)')ics,int(qset(ntry3+9))
```

```
*
*
*  The  aircraft which is the target is
*     taken from the missile information.
*
          ntry6 = locat(ics.n16)
          ntry7 = locat(ics.n17)
*         if (tnow.gt.860) write(8,'(5x,'Point 1')')
          if (qset(ntry7+10).lt.111) then
            do  7010  j2 = 1,10
              qset(ntry3+j2) = 0
 7010       continue
            write(8,'(5x,a5,2x,i2,' radar missile went ballistic, ',
     1        'target ',a5,2x,i4,' already dead, Time:  ',f12.2)')cs1,
     2         i1,cs2,ics,tnow
            return
          endif
          if (qset(ntry2+9).lt.2.5) then
            do  7008  j2 = 1,10
              qset(ntry3+j2) = 0
 7008       continue
            write(8,'(5x,a5,2x,i3,' radar missile went ballistic, ',
     1        'lost radar lock, Time:  ',f12.2)')cs1,i1,tnow
            return
          endif
*
*  The pointer to the target aircraft's position
*     is located.
*
          do  7032  j2 = 1,3
            vb1(j2) = qset(ntry3+j2)
            vb2(j2) = qset(ntry3+3+j2)
            vr1(j2) = qset(ntry6+j2)
            vr2(j2) = qset(ntry6+3+j2)
7032      continue
*         if (tnow.gt.860) write(8,'(5x,'Point 2')')
*
*
*  The positional and velocity vectors of the
*     aircraft and missile are loaded into
*     scratch arrays.
*
          call los(vb1,vr1,flos,xmag,phi1)
          call los(vr1,vb1,tlos,xmag,phi2)
*
*  The lines of sight (LOS) are calculated.
*     'los' returns a unit vector oriented
*     along the LOS, its magnitude, and its
*     depression or elevation above the
*     horizon.
*
          vel = qset(ntry3+7)
*         if ((db(5)).and.(tnow.gt.860))
*    +    write(8,'(5x,'Speed is ',f8.3,' feet/sec')')vel
```

```
*
*  The missile velocity is extracted.
         call cross(tlos,vr2,vr3,uvec1)
         call cross(uvec1,tlos,vr3,uvec1)
         call dot(vr2,tlos,dprod,c,theta)
*        if (tnow.gt.860) write(8,'(5x,'Point 3')')
*
*  'cross' and 'dot' are vector manipulation
*     subroutines which return vector and
*     scalar products of two vectors.
*
         tcomp = abs(sin(theta))*qset(ntry6+7)
         rcomp = sqrt(qset(ntry3+7)**2-tcomp**2)
*
*  'tcomp' and 'rcomp' are the tangential and radial
*     components of the aircraft's velocity relative
*     to its line of sight to the missile.
*
         do  6034  j2 = 1,3
           uvec1(j2) = uvec1(j2)*tcomp
           flos(j2) = flos(j2)*rcomp
           vb2(j2) = uvec1(j2)+flos(j2)
6034     continue
*        if (tnow.gt.860) write(8,'(5x,'Point 4')')
*
*
*  The missile's velocity is decomposed along the
*     LOS and then the components are added to give
*     the intercept vector.
*
         call unit(vb2,vb2)
         do  36  j2 = 1,3
           qset(ntry3+3+j2) = vb2(j2)
           qset(ntry3+j2) = qset(ntry3+j2)+qset(ntry3+3+j2)*dtnow*
     *       qset(ntry3+7)
           vb1(j2) = qset(ntry3+j2)
  36     continue
         call los(vb1,vr1,flos,xmag,phi)
         qset(ntry3+8) = qset(ntry3+8)-dtnow
         if (qset(ntry3+8).lt.0) then
           do  48  j2 = 1,10
             qset(ntry3+j2) = 0
  48       continue
           go to 50
         endif
*
*  The missile's Time of Flight (TOF) is
*     decremented.
*
         comp = qset(ntry3+10)-xmag
*        if (tnow.gt.860) write(8,'(5x,'Point 5')')
*
*  The missile's range is compared with the
*     previous range.  If it is greater the
```

```
*     missile has reached its point of
*     closest approach to the target.
*
            if (comp.lt.0) then
              do  40  j2 = 1,10
                qset(ntry3+j2) = 0
  40          continue
              pk = .75
              if (n4.eq.8) pk = .5
              if ((abs(theta).gt.1.04712).and.(abs(theta).lt.2.09424))
     +        then
                pk = .5
                if (n4.eq.8) pk = .15
              endif
*           if (tnow.gt.860) write(8,'(5x,'Point 6')')
              if ((n4.eq.8).and.(asin(qset(ntry1+6)).gt..17365)) pk = 0
*
*  A probability of Kill (pk) is assigned
*    based on the relationship of the the
*    missile to the target at time of closest
*    approach.
*
*           if (tnow.gt.860) write(8,'(5x,'Point 7')')
            comp = unfrm(0.,1.,9)
            if (comp.lt.pk) then
              if (n4.eq.3) then
                if (ivthrt(i1).eq.ics) then
                  ivthrt(i1) = 0
                  vthrt(i1) = 999999
                endif
                nthrt(i1) = 0
                ntrr(ics) = 0
                qset(ntry7+10) = 102
                qset(ntry7+9) = 0
                qset(ntry7+8) =tnow
                do  7052  j2 = 1,11
                  thrt(i1,j2) = 999999
                  ithrt(i1,j2) = 0
                  thtrr(ics,j2) = 999999
                  itrr(ics,j2) = 0
 7052           continue
                n8 = locat(i1,2)
                if (qset(n8+1).gt.0) then
                  n5 = qset(n8+1)
                  n6 = locat(n5,1)
                  n7 = locat(n5,2)
                  qset(n7+1) = 0
                  qset(n7+6) = 1
                endif
                qset(ntry2+9) = 0
              endif
*           if (tnow.gt.860) write(8,'(5x,'Point 9')')
              if (n4.eq.8) then
                ntrr(i1) = 0
```

```
                do 7054 j2 = 1,11
                  itrr(i1,j2) = 999999
                  thtrr(i1,j2) = 0
 7054           continue
                n8 = locat(i1,7)
                if (qset(n8+1).gt.0) then
                  n5 = qset(n8+1)
                  n6 = locat(n5,6)
                  n7 = locat(n5,7)
                  qset(n7+1) = 0
                  qset(n7+6) = 1
                endif
                qset(ntry2+9) = 0
                qset(ntry7+10) = 102
                qset(ntry7+9) =0
                qset(ntry7+8) = tnow
              endif
              do  38  j2 = 1,10
                qset(ntry3+j2) = 0
   38         continue
*
*  A random number is drawn and compared against
*    the pK value.  If the pK is larger, the
*    aircraft is considered a loss.
*  The missile information is cleared from
*     File 3 and the aircraft is given
*     a mission code reflecting its
*     being shot down by a radar missile.
*
              if (db(5))
     +          write(8,'(5x,a5,2x,i3,' shot down by radar missile, '
     +          'coord N',f12.2,', E',f12.2,' Time: ',f12.2)')cs2,ics,
     +          qset(ntry6+1),qset(ntry6+2),tnow
              if (n11.eq.1) then
                xx(4) = xx(4) + 1
                xx(7) = xx(7) + 1
                n5 = qset(ntry7+1)
                if (n5.gt.0) then
                  n7 = locat(n5,n17)
                  qset(n7+6) = 1
                  qset(n7+1) = 0
                endif
              else
                n5 = qset(ntry7+1)
                if (n5.gt.0) then
                  n7 = nsucr(ntry7)
                  qset(n7+6) = 1
                  qset(n7+1) = 0
                endif
                xx(3) = xx(3) + 1
                xx(5) = xx(5) + 1
              endif
            else
              do 42 j2 = 1,10
```

```
                  qset(ntry3+j2) = 0
42              continue
                if (db(5))
     +          write(8,'(5x,a5,2x,i4,' survived radar missile from '
     +            a5,2x,i3,' Time ',f12.2)')cs2,ics,cs1,i1,tnow
              endif
            else
*           if (tnow.gt.850) write(8,'(5x,'Point 10')')
              qset(ntry3+1Q) = xmag
            endif
*           if (tnow.gt.850) write(8,'(5x,'Point 11')')
50      return
        end
```

```
      subroutine cmp80(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*    i1:  aircraft callsign
*    n2:  mission code derivative
*    n3:  wingman's call sign
*    n4:  blue/red file pointer
*
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  vec1(3),flos(3),
     1 vb1(3),vb2(3),vr1(3),vr2(3),a(10)
      if (db(10)) write(8,'(5x,'Cmp80, Time ',f9.2)')tnow
 8000 ntry6 = locat(i1,6)
      ntry7 = locat(i1,7)
      if ((ivtrr(i1).gt.0).and.(qset(ntry7+4).gt.0)) then
        n10 = ivtrr(i1)
        n11 = locat(n10,1)
        do 8004 j1 = 1,3
          vr1(j1) = qset(ntry6+j1)
          vr2(j1) = qset(ntry6+3+j1)
          vb1(j1) = qset(n11+j1)
          vb2(j1) = qset(n11+3+j1)
 8004   continue
        call los(vr1,vb1,flos,xmag,phi)
        if (xmag.gt.5000) go to 8008
        call dot(flos,vb2,dprod,c,theta)
        if (abs(theta).gt.(30./57.3)) go to 8008
        call dot(vr2,flos,dprod,c,theta)
        if (abs(theta).lt.(30./57.3)) then
          qset(ntry7+4) = qset(ntry7+4) - 1
          do 8006  j1 = 1,3
            a(j1) = qset(ntry6+j1)
            a(j1+3) = qset(ntry6+3+j1)
 8006     continue
          a(7) = qset(ntry6+7)
          a(8) = 22
          a(9) = ivtrr(i1)
          a(10) = xmag
          call filem(9,a)
          write(8,'(5x,'Red ',i3,' launched heatseeker at Blue ',i2,
     +      ', Time ',f9.2)')i1,ivtrr(i1),tnow
          xx(14) = xx(14) + 1
          ivtrr(i1) = 0
          vtrr(i1) = 999999
        endif
      endif
```

```
 8008 n1 = qset(ntry7+8)
      nr1 = 1
      if (n1.eq.3) nr1 = 2
      if (n1.eq.5) nr1 = 3
      n2 = qset(ntry7+9)
      ntry10 = locat(n2,10)
      vr1(1) = qset(ntry6+1)
      vr1(2) = qset(ntry6+2)
      vr1(3) = 0
      vec1(1) = qset(ntry10+n1)
      vec1(2) = qset(ntry10+n1+1)
      vec1(3) = 0
      call los(vr1,vec1,flos,rng,phi)
      if (rng.le.3000) then
        if (i1.eq.1)
     +    write(8,'(5x,'Waypoint ',i2,', Route # ',i2,', Red ',i4,
     +      ', Time:  ',f8.2)')n2,nr1,i1,tnow
      if (i1.eq.1)
     + write(8,'(5x,'Range to Waypoint ',i2,2x,f9.2,' ft.')')n2,rng
      if (i1.eq.1)
     + write(8,'(5x,'Ftr pos:  ',3('X(',i1,'):',f11.2,2x))')
     + (j2,qset(ntry6+j2),j2=1,3)
      if (i1.eq.1)
     + write(8,'(5x,'Waypt Pos: ',3('X(',i1,'):',f11.2,2x))')
     + (j2,vec1(j2),j2=1,3)
          qset(ntry7+9) = qset(ntry7+9)+1
          ntry10 = nsucr(ntry10)
          if (qset(ntry10+n1).eq.999) then
            write(8,'(5x,'Red ',i4,' landed at Time:  ',f8.2)')i1,tnow
            qset(ntry7+10) = 100
            qset(ntry7+9) = tnow
          endif
          return
        endif
        do  8010  j1 = 1,3
          vr1(j1) = qset(ntry6+3+j1)
 8010   continue
        call dot(vr1,flos,dprod,c,theta)
        if (theta.gt.(5./57.3))
     +    call turn(vr1,flos,2.0,ntry6,dtnow,qset(ntry6+7))
      return
      end
```

```
      subroutine cmp90(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*    i1:  aircraft callsign
*    n2:  mission code derivative
*    n3:  wingman's call sign
*    n4:  blue/red file pointer
*
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  vec1(3),vec2(3),uvec1(3)
      if (db(10)) write(8,'(5x,'Cmp90, Time ',f9.2)')tnow
*
 9000 do  9010  j1 = 1,3
        vec1(j1) = qset(ntry1+j1)
        vec2(j1) = qset(ntry1+3+j1)
 9010 continue
*
*   Establish the line of sight between the
*    aircraft and the base.
*
      call los(vec1,blue,uvec1,rng,phi)
      if (rng.lt.3000) then
        qset(ntry2+10) = 105
        write(8,'(5x,'Blue ',i2,' landed at Time:  ',f8.2)')i1,tnow
      endif
      qset(ntry1+9) = 700
      if (rng.le.60000) qset(ntry1+9) = 585
*
*   Check airspeed to see if it is
*     the desired airspeed.
*
      dlas = qset(ntry1+9)-qset(ntry1+7)
      if (abs(dlas).lt.5) then
        qset(ntry1+9) = qset(ntry1+7)
      else
        accel = 5
        if (dlas.lt.0) accel = -5
        qset(ntry1+7) = qset(ntry1+7)+accel
      endif
      if (phi.le.atan(1./12.)) then
        if (qset(ntry2+9).gt.1.5) go to 9020
*
*   Decide whether to level off or climb.
*
        qset(ntry1+10) = min(-20000,qset(ntry1+3))
        delta = qset(ntry1+10)-qset(ntry1+3)
```

```
      uvec1(3) = 0
 9020 if ((abs(delta).le.200).and.(qset(ntry1+6).ge.
    +  (-16.7/qset(ntry1+7)))) then
        qset(ntry2+9) = 2
        call unit(uvec1,uvec1)
        do  9012  j1 = 1,3
          qset(ntry1+3+j1) = uvec1(j1)
 9012   continue
        return
      else
*
*   If the aircraft is not pointed within
*     a few degrees of home, turn him.
*
        call turn(vec2,uvec1,2.5,ntry1,dtnow,qset(ntry1+7))
        return
      endif
      call dot(vec2,uvec1,dprod,c,theta)
      if (abs(theta).le.0.01745) then
        do  9014  j1 = 1,3
          qset(ntry1+3+j1) = uvec1(j1)
 9014   continue
      else
        call turn(vec2,uvec1,2.0,ntry1,dtnow,qset(ntry1+7))
      endif
      endif
      return
      end
```

```
      subroutine cmp100(i1,n2,n3,n4)
*  The dummy variaoles represent the following:
*
*    i1:  aircraft callsign
*    n2:  mission code derivative
*    n3:  wingman's call sign
*    n4:  blue/red file pointer
*
***********************************************************************
*                                                                     *
*  This section runs Blue intercepts and                              *
*    executes Blue tactics.                                           *
*                                                                     *
***********************************************************************
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      character  cs3*6
      dimension  vec(3),vec1(3),vec2(3),uvec(3),flos(3),
       ),vb1       (3),v       b2(3)  ,vr1(3),vr2(3),a(10)
      if (db(10)) write(8,'(5x,'Cmp100, Time ',f9.2)')tnow
*
      ntry1 = locat(i1,1)
      ntry2 = locat(i1,2)
      if (ivthrt(i1).gt.0) then
        n6 = locat(ivthrt(i1),7)
        if (qset(n6+10).lt.111) then
          ivthrt(i1) = 0
          vthrt(i1) = 999999
          go to 150
        endif
*
*
*  If the visually detected target is also
*    a radar contact to which the pilot is
*    locked up, the visual routine ignores
*    it.
*
        if (qset(ntry2+9).gt.1.5) then
          if (ivthrt(i1).eq.ithrt(i1,11)) then
            if (db(5))
     +      write(8,'(5x,'Blue ',i3,' has tally-ho on Red ',i3,
     +      ' (tgt of intcp) at Time ',f9.2)')i1,ivthrt(i1),tnow
            go to 150
          endif
        endif
      if ((qset(ntry2+9).gt.1.5).and.(vthrt(i1).gt.18000)) go to 10000
        if (db(5))
```

```
      +  write(8,'(5x,'Blue ',i3,' has tally-ho on Red ',i3,' at Time'
      +     ,f9.2)')i1,ivthrt(i1),tnow
         ntry6 = locat(ivthrt(i1),6)
         do  112  j1 = 1,3
           vb1(j1)= qset(ntry1+j1)
           vb2(j1) = qset(ntry1+3+j1)
           vr1(j1) = qset(ntry6+j1)
           vr2(j1) = qset(ntry6+3+j1)
 112     continue
*
*   If the pilot is reacting to a visual
*     threat he tries to turn hard and
*     point at him in order to use his
*     weapons.
*
*
*
         call los(vr1,vb1,tlos,xmag,phi)
         call dot(vr2,tlos,dprod,c,theta)
         if (abs(theta).ge..52356) go to 150
         n5 = qset(ntry2+1)
         if (n5.gt.0) then
           n7 = locat(n5,2)
           qset(n7+1) = 0
           qset(n7+6) = 1
         endif
         qset(ntry2+1) = 0
         qset(ntry2+6) = 1
         qset(ntry2+7) = xmag
         n2 = 11
         qset(ntry2+10) = 121
         qset(ntry2+9) = 4
         if (db(5))
      +  write(8,'(5x,'Blue ',i3,' reacting visually to  '
      +     'Red ',i2,',  Time ',f9.2)')i1,ivthrt(i1),tnow
         call cmp110(i1,n2,n3,n4)
         return
       endif
 150   continue
*   Cmp100 is the workhorse of this program.
*     It runs intercepts and fires missiles.
*
*   If the aircraft is locked on, go to a
*     different section.
*
10000 continue
       if (qset(ntry2+6).eq.2) go to 10092
       if (qset(ntry2+9).gt.1.5) go to 10050
*
*   An aircraft which has lost its radar
*     lock either through the target being
*     killed or some other occurance has
*     a code of zero.
*
```

```
10088 if (qset(ntry2+9).eq.0) then
        if (nthrt(i1).eq.0) then
*
*    If no visual nor radar targets, check
*       for an empty CAP and assign fighter
*       to it.
*
          do  10018  j1 = 1,3
            if (ncap(j1).eq.0) then
              qset(ntry2+10) = 110+j1
              qset(ntry2+9) = 3
              n2 = j1
              n3 = qset(ntry2+1)
              n4 = 0
              n5 = qset(ntry2+1)
              if (n5.gt.0) then
                n7 = locat(n5,2)
                if (qset(n7+9).gt.1.5) then
                  qset(n7+1) = 0
                  qset(n7+6) = 1
                else
                  qset(n7+10) = 110 + j1
                  qset(n7+9) = 3
                endif
              endif
              call cmp10(i1,n2,n3,n4)
              return
            endif
10018   continue
*
*    Otherwise, send to CAP 2.
*
          qset(ntry2+10) = 112
          qset(ntry2+9) = 3
          n2 = 2
          n5 = qset(ntry2+1)
          if (n5.gt.0) then
            n7 = locat(n5,2)
            if (qset(n7+9).gt.1.5) then
              qset(n7+1) = 0
              qset(n7+6) = 1
            else
              qset(n7+10) = 110 + j1
              qset(n7+9) = 3
            endif
          endif
          call cmp10(i1,n2,n3,n4)
          return
        endif
        endif
*
*    If coming into the section on a radar
*      intercept, sort through the radar
*      contact file looking for targets.
```

```
*
10150 nt1 = min(10,nthrt(i1))
      do  10002  j1 = 1,nt1
        ics = ithrt(i1,j1)
        if (ics.gt.o) then
          ntry6 = locat(ics,6)
          ntry7 = locat(ics,7)
          if (qset(ntry7+10).lt.111) go to 10002
          if (qset(ntry6+2).le.10389200) then
            if (qset(ntry2+10).ne.120) then
              qset(ntry2+10) = 120
              qset(ntry2+9) = 1
              if (qset(ntry2+6).eq.1) then
                ithrt(i1,1) = ithrt(i1,j1)
                ithrt(i1,11) = ithrt(i1,j1)
                thrt(i1,1) = thrt(i1,j1)
                thrt(i1,11) = thrt(i1,j1)
                do  10030  j2 = 2,10
                  thrt(i1,j2) = 999999
                  ithrt(i1,j2) = 0
10030           continue
                nthrt(i1) = 1
                if (qset(ntry2+1).ne.0) then
                  n6 = qset(ntry2+1)
                  n7 = locat(n6,2)
                  qset(n7+10) = 120
                  qset(n7+9) = 1
                endif
              endif
            endif
            go to 10004
          endif
        endif
10002 continue
*
*   If there were no radar contacts,
*     go back to the cap.
*
      nthrt(i1) = 0
      do 10090 j2 = 1,11
        thrt(i1,j2) = 999999
        ithrt(i1,j2) = 0
10090 continue
      qset(ntry2+9) =0
      if (qset(ntry2+1).ne.0) then
        n6 = qset(ntry2+1)
        n7 = locat(n6,2)
        if (qset(n7+9).gt.1.5) then
          qset(ntry2+1) = 0
          qset(n7+1) = 0
          qset(n7+6) = 1
          go to 10088
        endif
        qset(n7+9) = 0
```

```
      endif
      go to 10088
10092 n5 = qset(ntry2+1)
      n6 = locat(n5,1)
      n7 = locat(n5,2)
      if (qset(ntry2+6).eq.2) then
        delta = qset(ntry1+10) - qset(ntry1+3)
        if (abs(delta).lt.500) then
          do 10100 j2 = 1,3
            qset(ntry1+3+j2) = qset(n6+3+j2)
10100     continue
          go to 10004
        endif
        phi = 30./57.3
        theta = 20./57.3
        if (qset(n7+8).lt.0) phi = -30./57.3
        if (delta.lt.0) theta = -20./57.3
        vb2(1) = qset(n6+4)*cos(phi)+qset(n6+5)*sin(phi)
        vb2(2) = qset(n6+4)*(-cos(theta))*sin(phi)
     +            +qset(n6+5)*cos(theta)*cos(phi)
     +            +qset(n6+6)*cos(theta)
        vb2(3) = qset(n6+4)*sin(theta)*sin(phi)
     +            +qset(n6+5)*(-sin(theta))*cos(phi)
     +            +qset(n6+6)*cos(theta)
        call unit(vb2,vb2)
        do 10098 j2 = 1,3
          qset(ntry1+3+j2) = vb2(j2)
10098   continue
      endif
10004 if (thrt(i1,1).le.90000) then
*
*   If the range to a target is less
*      than 15 nautical miles, lock on.
*      This also cleans out the radar
*      contact file, as there is no
*      radar search when locked on.
*
        if (qset(ntry2+6).eq.1) then
*       if (i1.eq.1)
*    +    write(8,'(5x,'Blue 1 locking on to Red ',i2,', Range ',
*    +    f5.1,' NM, Time ',f9.2)')ics,ithrt(i1,1)/6000.,tnow
          qset(ntry2+9) = 2
          go to 10050
        endif
        if (qset(ntry2+6).eq.2) then
          n5 = qset(ntry2+1)
          n6 = locat(n5,1)
          n7 = locat(n5,2)
          if((ithrt(i1,1).eq.ithrt(n5,11)).and.
     +      (qset(n7+9).gt.1.5)) then
            if (nthrt(i1).lt.2) return
            if (thrt(i1,2).gt.90000) return
            ithrt(i1,11) = ithrt(i1,2)
            thrt(i1,11) = thrt(i1,2)
```

```
              ithrt(i1,1) = ithrt(i1,2)
              thrt(i1,1) = thrt(i1,2)
              qset(n7+1) = 0
              qset(ntry2+1) = 0
              qset(ntry2+6) = 1
              qset(ntry2+9) = 2
              qset(ntry2+10) = 120
              go to 10050
            endif
            if ((n5.gt.0).and.(qset(n7+9).gt.1.5)) then
              qset(ntry2+6) = 1
              qset(ntry2+1) = 0
              qset(ntry2+9) = 2
              qset(ntry2+10) = 120
              qset(n7+6) = 1
              qset(n7+1) = 0
            endif
            if ((n5.gt.0).and.(qset(n7+9).lt.1.5)) then
              qset(n7+1) = i1
              qset(n7+6) = 2
              qset(n7+9) = 1
              qset(n7+10) = 120
              qset(ntry2+6) = 1
              qset(ntry2+9) = 2
              qset(ntry2+10) = 120
            endif
          endif
        endif
*
*   Get vectors for intercept calculations.
*
10050 ics = ithrt(i1,11)
        if (ithrt(i1,2).gt.0) then
          do 10016 j2 = 2,10
            ithrt(i1,j2) = 0
            thrt(i1,j2) = 999999
10016     continue
        endif
        if (ics.le.0) then
          qset(ntry2+9) = 0
          do 10062 j1 = 1,11
            ithrt(i1,j1) = 0
            thrt(i1,j1) = 999999
10062     continue
          nthrt(i1) = 0
          return
        endif
        ntry6 = locat(ics,6)
        ntry7 = locat(ics,7)
*
*   Decide on type of attack:  from above or below.
*
        cs3 = 'below'
        qset(ntry1+10) = qset(ntry6+3)+5000
```

```
        if (qset(ntry6+3).gt.-7000) then
          qset(ntry1+10) = qset(ntry6+3)-8000
          cs3 = 'above'
        endif
*       if (i1.eq.1)
*      +  write(8,'(5x,'Target Red ',i2,', altitude ',f9.2,' ft.',
*      +  '  Attack will be from ',a5,'.'/10x,'Attack altitude ',f9.2,
*      +  ' ft.')')ics,-qset(ntry6+3),cs3,-qset(ntry1+10)
        n5 = qset(ntry2+1)
        if ((n5.gt.0).and.(qset(ntry2+6).eq.2)) then
          n6 = locat(n5,1)
          qset(n6+10) = qset(ntry1+10) + 2000
          if (qset(ntry6+3).gt.-9000) qset(n6+10) = qset(ntry1+10) - 5000
        endif
*
*    Check to see if the target you are
*      locked on to is dead. (Your missile
*      or someone else's may have killed
*      him.)
*
        if (qset(ntry7+10).lt.111) then
         qset(ntry2+9) = 0
         do 10066 j1 = 1,11
           ithrt(i1,j1) = 0
           thrt(i1,j1) = 999999
10066    continue
         return
        endif
        do  10006  j1 = 1,3
          vec1(j1) = qset(ntry1+j1)
          vec2(j1) = qset(ntry6+j1)
10006 continue
        call los(vec1,vec2,flos,xmag,phi)
*       if (i1.eq.1)
*      +  write(8,'(5x,'Blue 1 intercepting Red ',i2,', Range ',f7.2,
*      +     ' NM, Time ',f9.2)')ics,xmag/6000.,tnow
        rngint  = xmag
        thrt(i1,1) = xmag
        thrt(i1,11) = xmag
        do  10008  j1 = 1,3
          tlos(j1) = -flos(j1)
10008 continue
*
*  INTERCEPT COURSE Section
*
*
*   Set desired airspeed at 1.2 * target's for
*      intercept.
*
        qset(ntry1+9) = min(1000,1.2*qset(ntry6+7))
        do  10010  j1 = 1,3
          vec1(j1) = qset(ntry1+3+j1)
          vec2(j1) = qset(ntry6+3+j1)
10010 continue
```

```
*
*   The intercept course is computed in the same
*     manner as in the missile section.  The target's
*     velocity is decomposed into two components,
*     one along the line of sight from the fighter to
*     the target and the other perpendicular to the
*     LOS and in the plane of the target's velocity
*     and the LOS.  The fighter's velocity is then
*     decomposed in the same manner, matching the
*     perpendicular component of the target and
*     applying the rest along the line of sight.
*     The resultant vector is the vector from the
*     fighter's position to the intercept point.
*
      call cross(tlos,vec2,vec,uvec)
      call cross(uvec,tlos,vec,uvec)
      call dot(vec2,tlos,dprod,c,theta)
      tcomp = abs(sin(theta))*qset(ntry6+7)
      tgtrdl = abs(cos(theta))*qset(ntry6+7)
      rcomp = sqrt(qset(ntry1+7)**2-tcomp**2)
      xmag = 0
      tmag = 0
      do 10012  j1 = 1,3
        uvec(j1) = uvec(j1)*tcomp
        flos(j1) = flos(j1)*rcomp
        fvec(j1) = uvec(j1)+flos(j1)
        xmag = xmag+fvec(j1)*fvec(j1)
        tmag = tmag + flos(j1) * flos(j1)
10012 continue
      xmag = sqrt(xmag)
      tmag = sqrt(tmag)
      tintcp = rngint/(tmag + tgtrdl)
      do  10014  j1 = 1,3
        fvec(j1) = fvec(j1)/xmag
        uvec(j1) = fvec(j1)
10014 continue
      if (rngint.lt.48000) go to 10020
      delta = qset(ntry1+10) - qset(ntry1+3)
      if (abs(delta).lt.500) then
        fvec(3) = 0
        call unit(fvec,fvec)
        go to 10020
      endif
      clmb = 30./57.3
      if (delta.lt.0) clmb = -30./57.3
      fvec(3) = fvec(3) + clmb
      call unit(fvec,fvec)
10020 continue
      do  10052  j1 = 1,3
        vb1(j1) = qset(ntry1+j1)
        vb2(j1) = qset(ntry1+3+j1)
        vr1(j1) = qset(ntry6+j1)
        vr2(j1) = qset(ntry6+3+j1)
```

```
10052 continue
*
*   Check to see if any of the tactical
*     ranges of the missiles have been
*     met.
*
      call los(vb1,vr1,flos,xmag,phi1)
      call los(vr1,vb1,tlos,xmag,phi2)
      call dot(vb2,flos,dprod,c,theta1)
      call dot(vr2,flos,dprod,c,theta2)
      rmax = 12000+42000*sin(abs(theta2)/3.)
      rmin = 3000+12000*sin(abs(theta2)/3.)
      htmax = 6000+18000*sin(abs(theta2)/3)+qset(ntry6+3)/4.
      htmin = 1000+5000*sin(abs(theta2)/3.)+5*(qset(ntry6+3)/1000.)**2
*     if (i1.eq.1)
*    +  write(8,'(5x,'Missile Employment Ranges are:  '/10x,
*    +  'Radar Missiles:  Max Range:  ',f9.2,' ft, Min Range:  ',
*    +  f9.2)')rmax,rmin
*     if (i1.eq.1)
*    +  write(8,'(10x,'Heat Missiles:   Max Range:  ',f9.2,' ft',
*    +  ' Min Range:  ',f9.2)')htmax,htmin
      if (qset(ntry2+9).gt.2.5) then
*     if (i1.eq.1)
*    +  write(8,'(5x,'Intercept Calculations: Ftr Blue 1, ',
*    +  'Tgt Red ',i2,', Intcpt in ',f7.2,' seconds.')')
*    +  ics,tintcp
*     if (i1.eq.1)
*    +  write(8,'(5x,'Ftr Speed ',f7.2,' fps, Tgt Speed ',f7.2,
*    +  ' fps.')')qset(ntry1+7),qset(ntry6+7)
*     if (i1.eq.1)
*    +  write(8,'(5x,'Ftr pos:  ',3('X(',i1,'):',f11.2,2x)/9x,'Vel:  ',
*    +  3('X(',i1,'):',f9.4,4x))')
*    +  (j2,qset(ntry1+j2),j2=1,3),(j2,qset(ntry1+3+j2),j2=1,3)
*     if (i1.eq.1)
*    +  write(8,'(5x,'Tgt pos:  ',3('X(',i1,'):',f11.2,2x)/9x,'Vel:  ',
*    +  3('X(',i1,'):',f9.4,4x))')(j2,vr1(j2),j2=1,3),
*    +  (j2,vr2(j2),j2=1,3)
*     if (i1.eq.1)
*    +  write(8,'(5x,'Ftr LOS:  ',(3('X(',i1,'):',f9.4,4x))/
*    +  5x,'Int vec:  ',3('X(',i1,'):',f9.4,4x))')
*    +  (j2,flos(j2),j2=1,3),(j2,uvec(j2),j2=1,3)
         rtheta = atan(qset(ntry1+7)/(2.5*32.2))
         if (abs(theta1).gt.abs(rtheta)) then
           call turn(vb2,flos,2.5,ntry1,dtnow,qset(ntry1+7))
         else
           do 10064 j1 = 1,3
             qset(ntry1+3+j1) = flos(j1)
10064      continue
         endif
         ntry3 = locat(i1,3)
         if (qset(ntry3+8).le.0) qset(ntry2+9) = 2
         return
      endif
*
```

```
*   If range to target is within missile
*     range, select a weapon and launch.
*
          if ((xmag.le.htmax).and.(xmag.ge.htmin)) then
*         if (i1.eq.1)
*     +     write(8,'(5x,'Within IR Range, tgt must  be within 20 ',
*     +     'degrees of nose.'/10x,'Target bears ',f5.1,' degrees off',
*     +     ' nose.')')theta1*57.3
            if ((abs(theta1).lt..26178).and.(qset(ntry2+4).gt.0)) then
              qset(ntry2+4) = qset(ntry2+4)-1
              qset(ntry2+9) = 0
              do 10068 j1 = 1,11
                ithrt(i1,j1) = 0
                thrt(i1,j1) = 999999
10068         continue
              nthrt(i1) = 0
*
*   Load the missile into the missile file.
*
              do  10054  j1= 1,3
                a(j1) = qset(ntry1+j1)
                a(j1+3) = qset(ntry1+3+j1)
10054         continue
              a(7) = qset(ntry1+7)+1000
              a(8) = 43
              a(9) = ics
              a(10) = xmag
              call filem(4,a)
              write(8,'(5x,'Blue ',i2,' launched heatseeker at Red ',
     1          i3,', Range ',f10.2,', Time:  ',f8.2)')i1,ics,xmag,tnow
              xx(12) = xx(12) + 1
              return
            endif
            rtheta = atan(qset(ntry1+7)/(5.0*32.2))
            if (abs(theta1).gt.abs(rtheta)) then
              call turn(vh2,flos,5.0,ntry1,dtnow,qset(ntry1+7))
            else
              do 10070 j1 = 1,3
                qset(ntry1+3+j1) = flos(j1)
10070         continue
            endif
            return
          endif
*
*   If unable to fire a heat missile but still outside
*     minimum range for a radar missle, select radar.
*
            if ((xmag.ge.rmin).and.(xmag.le.rmax)) then
*           if (i1.eq.1)
*     +       write(8,'(5x,'Target within radar range, must be within ',
*     +       '40 degrees of nose.'/10x,'Tgt bears ',f5.1,' degrees ',
*     +       'off nose.')')theta1*57.3
              if ((theta1.le.0.52356).and.(qset(ntry2+3).gt.0)) then
                qset(ntry2+3) = qset(ntry2+3)-1
```

```
                qset(ntry2+9) = 3
                do  10058  j1 = 1,3
                  a(j1) = qset(ntry1+j1)
                  a(j1+3) = qset(ntry1+3+j1)
10058           continue
                a(7) = qset(ntry1+7)/2.+1000
                a(8) = 90
                a(9) = ics
                a(10) = xmag
                ntry3 = locat(i1,3)
                do  10060  j1 = 1,10
                  qset(ntry3+j1) = a(j1)
10060           continue
                write(8,'(5x,'Blue ',i2,' launched radar missile at ',
     1            'Red ',i3,', Range ',f10.2,', Time:  ',f8.2)')i1,ics,
     2             xmag,tnow
                xx(11) = xx(11) + 1
                return
              endif
            endif
*
*   Once the intercept vector is calculated, turn
*     the fighter toward it.
*
*     if (i1.eq.1)
*    +  write(8,'(5x,'Intercept Calculations: Ftr Blue 1, ',
*    +  'Tgt Red ',i2,', Intcpt in ',f7.2,' seconds.')')
*    +  ics,tintcp
*     if (i1.eq.1)
*    +  write(8,'(5x,'Ftr Speed ',f7.2,' fps, Tgt Speed ',f7.2,
*    +  ' fps.')')qset(ntry1+7),qset(ntry6+7)
*     if (i1.eq.1)
*    +  write(8,'(5x,'Ftr pos:  ',3('X(',i1,'):',f11.2,2x)/9x,'Vel:  ',
*    +  3('X(',i1,'):',f9.4,4x))')
*    ,  (j2,qset(ntry1+j2),j2=1,3),(j2,qset(ntry1+3+j2),j2=1,3)
*     if (i1.eq.1)
*    +  write(8,'(5x,'Tgt pos:  ',3('X(',i1,'):',f11.2,2x)/9x,'Vel:  ',
*    +  3('X(',i1,'):',f9.4,4x))')(j2,vr1(j2),j2=1,3),
*    +  (j2,vr2(j2),j2=1,3)
*     if (i1.eq.1)
*    +  write(8,'(5x,'Ftr LOS:  ',(3('X(',i1,'):',f9.4,4x))/
*    +  5x,'Int vec:  ',3('X(',i1,'):',f9.4,4x))')
*    +  (j2,flos(j2),j2=1,3),(j2,uvec(j2),j2=1,3)
      call dot(vec1,fvec,dprod,c,theta)
      qset(ntry2+8) = -1
      if (theta.gt.0) qset(ntry2+8) = 1
      rtheta = atan(qset(ntry1+7)/(3.5*32.2))
      if (rtheta.lt.abs(theta)) then
        call turn(vec1,fvec,3.5,ntry1,dtnow,qset(ntry1+7))
      else
        do 10152 j1 = 1,3
          qset(ntry1+3+j1) = fvec(j1)
10152   continue
        return
```

```
      endif
        end
```

```
      subroutine cmp110(i1,n2,n3,n4)
*  The dummy variables represent the following:
*
*    i1:  aircraft callsign
*    n2:  mission code derivative
*    n3:  wingman's call sign
*    n4:  blue/red file pointer
*
      common/scom1/atrib(100),dd(100),ddl(100),dtnow,ii,mfa,mstop,nclnr,
     1ncrdr,nprint,nnrun,nnset,ntape,ss(100),ssl(100),tnext,tnow,xx(100)
      common  qset(15000)
      common/ucom1/nsectr(6),ncap(3),nb,nr,ithrt(24,11),thrt(24,11),
     +nthrt(24),vthrt(24),ivthrt(24),blue(3),redb(3,3),
     +itrr(80,11),thtrr(80,11),ntrr(80),vtrr(80),
     +ivtrr(80)
      common/ucom2/db(20)
      logical  db(20)
      dimension  flos(3),
     1 tlos(3),vb1(3),vb2(3),vr1(3),vr2(3),a(10)
      if (db(10)) write(8,'(5x,'Cmp110, Time ',f9.2)')tnow
11000  ntry1 = locat(i1,1)
       ntry2 = locat(i1,2)
*
*   Visual Attack Section.
*
11002 ics = ivthrt(i1)
*     write(8,'(5x,'Blue ',i2,' in visual engagement with Red ',i3,
*    +  ', Time ',f9.2)')i1,ics,tnow
      if (ics.eq.0) then
        qset(ntry2+9) = 0
        qset(ntry2+10) = 120
        ivthrt(i1) = 0
        vthrt(i1) = 999999
        return
      endif
      ntry6 = locat(ics,6)
      ntry7 = locat(ics,7)
      if (qset(ntry7+10).lt.111) then
        qset(ntry2+10) = 120
        qset(ntry2+9) = 0
        vthrt(i1) = 999999
        ivthrt(i1) = 0
        return
      endif
      do  11010  j1 = 1,3
        vb1(j1) = qset(ntry1+j1)
        vb2(j1) = qset(ntry1+3+j1)
        vr1(j1) = qset(ntry6+j1)
        vr2(j1) = qset(ntry6+3+j1)
11010 continue
      call los(vb1,vr1,flos,xmag,phi)
      call dot(vb2,flos,dprod,c,theta1)
      call dot(vb2,vr2,dprod,c,theta2)
      if (abs(theta2).gt.(90./57.3).and.(xmag.le.3000)) then
```

```
            qset(ntry2+9) = 0
            qset(ntry2+10) = 120
            vthrt(i1) = 999999
            ivthrt(i1) = 0
            write(8,'(5x,'Blue ',i2,' disengaging from visual engage. with '
     +         'Red ',i3)')i1,ics
            return
          endif
*         if (i1.eq.1)
*    +    write(8,'(5x,'Blue 1 engaging Red ',i2,', Range ',f11.2,
*    +       ' ft, Time ',f9.2)')ics,xmag,tnow
*         if (i1.eq.1)
*    +    write(8,'(5x,'Ftr Speed ',f7.2,' fps, Tgt Speed ',f7.2,
*    +    ' fps.')')qset(ntry1+7),qset(ntry6+7)
*         if (i1.eq.1)
*    +    write(8,'(5x,'Ftr pos:  ',3('X(',i1,'):',f11.2,2x)/9x,'Vel:  ',
*    +    3('X(',i1,'):',f9.4,4x))')
*    +    (j2,qset(ntry1+j2),j2=1,3),(j2,qset(ntry1+3+j2),j2=1,3)
*         if (i1.eq.1)
*    +    write(8,'(5x,'Tgt pos:  ',3('X(',i1,'):',f11.2,2x)/9x,'Vel:  ',
*    +    3('X(',i1,'):',f9.4,4x))')(j2,vr1(j2),j2=1,3),
*    +    (j2,vr2(j2),j2=1,3)
*         if (i1.eq.1)
*    +    write(8,'(5x,'Ftr LOS:  ',3('X(',i1,'):',f9.4,4x))')
*    +    (j2,flos(j2),j2=1,3)
          rtheta = atan(qset(ntry1+7)/(6.0*32.2))
*
*    Turn hard toward the target and try
*      to get a heat missile shot.
*
          if (qset(ntry2+4).gt.0) then
            call los(vr1,vb1,tlos,xmag,phi2)
            call dot(vr2,tlos,dprod,c,theta2)
            htmax = 6000+18000*sin(abs(theta2)/3.)+qset(ntry6+3)/4.
            htmin = 1000+5000*sin(abs(theta2)/3.)
*         if (i1.eq.1)
*    +    write(8,'(10x,'Heat Missiles:   Max Range:  ',f9.2,' ft',
*    +    ' Min Range:  ',f9.2)')htmax,htmin
            if (xmag.lt.htmin) go to 11020
            if (abs(theta1).lt.0.17452) then
              if ((xmag.lt.htmax).and.(xmag.gt.htmin)) then
              do  11012  j1 = 1,3
                a(j1) = qset(ntry1+j1)
                a(j1+3) = qset(ntry1+3+j3)
11012           continue
                a(7) = qset(ntry1+7)+1000
                a(8) = tnow
                a(9) = ics
                a(10) = xmag
                call filem(4,a)
                write(8,'(5x,'Blue ',i2,' visually launched heatseeker at ',
     +            'Red ',i3,', Range ',f10.2,', Time ',f8.2)')i1,ics,xmag,
     +            tnow
                xx(12) = xx(12) + 1
```

```
                  qset(ntry2+4) = qset(ntry2+4)-1
                  qset(ntry2+9) = 0
                  qset(ntry2+10) = 120
                  vthrt(i1) = 999999
                  ivthrt(i1) = 0
                  do 11022  j1 = 1,11
                    ithrt(i1,j1) = 0
                    thrt(i1,j1) = 999999
11022             continue
                  nthrt(i1) = 0
                  return
                endif
              else
                rtheta = atan(qset(ntry1+7)/(6.0*32.2))
                if (abs(rtheta).lt.abs(theta1)) then
                  call turn(vb2,flos,6.0,ntry1,dtnow,qset(ntry1+7))
                else
                  do  11014 j1 = 1,3
                    qset(ntry1+3+j1) = flos(j1)
11014             continue
                endif
                qset(ntry2+7) = xmag
                return
              endif
            endif
*
*   If close, try for a gun shot.
*
11020 if (qset(ntry2+5).gt.2.0) then
              if (abs(rtheta).lt.abs(theta1)) then
                call turn(vb2,flos,6.0,ntry1,dtnow,qset(ntry1+7))
              else
                do  11016 j1 = 1,3
                  qset(ntry1+3+j1) = flos(j1)
11016           continue
              endif
              call dot(vr2,flos,dprod,c,theta2)
              guns = 1500+2500*sin(abs(theta2)/4.)
              if ((rng.le.guns).and.(abs(theta1).lt..17452)) then
                qset(ntry2+5) = qset(ntry2+5)-dtnow
                qset(ntry2+9) = qset(ntry2+9)+dtnow
                if((qset(ntry2+9)-4).ge.2) then
                  qset(ntry2+9) = 0
                  comp = unfrm(0.,1.,9)
                  pk = .1+sin(abs(theta2)/4.)
                  if (pk.ge.comp) then
                    ntry7 = locat(ics,7)
                    qset(ntry7+10) = 101
                    qset(ntry7+9) = i1
                    qset(ntry7+8) = tnow
                    write(8,'(5x,'Blue ',i2,', gun kill on Red ',i3,
     +                ', Time:  ',f8.2)')i1,ics,tnow
                    xx(10) = xx(10) + 1
                    xx(9) = xx(9) + 1
```

```
                  xx(4) = xx(4) + 1
                  qset(ntry2+10) = 120
                  qset(ntry2+9) = 0
                  ivthrt(i1) = 0
                  vthrt(i1) = 999999
                  return
                endif
                write(8,'(''Blue '',i2,'', unsuccessful gun shot on Red '',
     +            i3,'', Time: '',f8.2)')i1,ics,tnow
                xx(9) = xx(9) + 1
                vthrt(i1) = 999999
                ivthrt(i1) = 0
                qset(ntry2+10) = 120
                qset(ntry2+9) = 0
              endif
              qset(ntry2+7) = xmag
              return
            endif
          endif
          qset(ntry1+9) = 1000
          if (rtheta.lt.theta1) then
            call turn (vb2,flos,6.0,ntry1,dtnow,qset(ntry1+7))
          else
            do  11018  j1 = 1,3
              qset(ntry1+3+j1) = flos(j1)
11018       continue
          endif
          qset(ntry2+7) = xmag
          return
          end
```

Vita

Roy J. Bogusch was born 1 November 1946 in Del Rio, Texas. He graduated from Sanderson High School, Sanderson, Texas and attended the United States Air Force Academy, graduating in June, 1969 with a Bachelor of Science degree in Engineering. Following pilot training at Randolph Air Force Base, Texas and conversion to the F-4 Phantom at Davis-Monthan Air Force Base, Arizona, he flew the F-4 with the 469 Tactical Fighter Squadron, Korat Royal Thai Air Force Base, Thailand, in 1971 and 1972. Assigned to Bitburg Air Base, West Germany after leaving Southeast Asia, he served as weapons officer and flight commander in the 22nd and 525th Tactical Fighter Squadrons. Transitioning to the F-15 Eagle in 1977, he returned to Luke Air Force Base, Arizona in 1978, where he served as an F-15 instructor pilot until assigned to the School of Engineering, Air Force Institute of Technology in 1982.

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FILM